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ENGINEERING:

An Illustrated Weekly Journal.

EDITED BY WILLIAM H. MAW AND B. ALFRED RAWORTH.

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H.M. Office of Works, &c.,
13th April, 1916. E 67

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Assistant Works Engineer, ineligible for the Army, experienced in constructional and general engineering and upkeep of plant, primarily to superintend extension of present plant—permanent position if found satisfactory—for firm of manufacturers in Lancashire.—State age, full experience, together with salary required, accompanied by recent testimonials, to BOX W 85, LEE & NIGHTINGALE, Liverpool. E 69

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GRINDING-MACHINES.—No. XXIII.

By JOSEPH HORNER.

STEADIES or back-rests grow in complexity as the practice of grinding increases, and as the grinders are made of heavier proportions in the manufacturing machines. Steadies are more numerous than formerly, being spaced more closely, and are also used freely for short pieces of large diameter as well as for long slender articles, and the shoes generally make larger arcs of contact with the work that is being ground. The application of grinding-steadies is therefore not paralleled by that of the steadies used in the lathe. Neither is it necessary to prepare a zone for a steady to make contact with, as is done in lathe work. It is brought only lightly in contact in opposition to the wheel with sufficient pressure to prevent the work from yielding, and it may be readjusted as the piece being ground becomes reduced. Some elasticity is frequently provided, and also an abutment stop for gauging repetitive production. Analogies suggested by lathe work cannot therefore be applied closely to grinding practice. The conditions differ so widely by reason of the vast difference in speeds, and in the quantities of material removed, and the fact that the cutting is done with a revolving element, so that experience gathered in lathe work is not of much help in grinding practice.

The influence of vibration is the cardinal difference. An amount of vibration which would not be objectionable or perceptible in turning develops evils in grinding. This is primarily a result of high speeds and of the generation of heat, with consequent distortion of the work. Secondary causes lie in the machine itself, in an original bad design, or in the spindles, consequent on wear, or want of lubrication, or uneven driving-belts, or on badly-fitting centres. The diagnosis and the location of the mischief calls for the experience of the man in charge, who will make such adjustments as are necessary, and the provisions which his intuition suggests.

Primarily, correct centring is necessary if vibration is to be avoided. The machine centres must be true, and the holes must fit them accurately, and without the points bottoming. The holes should be drilled and reamed, 60 deg., as in lathe centres, being the standard angle. Dead centres require attention and correction, as well as live centres, since they wear out of truth. Centres are ground by setting the universal work-head to an angle of 30 deg., and traversing the revolving centre past the wheel. Plain machines that have heads which do not swivel have an attachment for holding the centres. This is clamped to the table, and carries a head set to the angle, in which head the centres are set and trued.

But when all precautionary measures have been taken, when the machine adjustments and the centring are satisfactory, the absolute necessity of using steadies remains. When turning is being done the function of a steady is mainly to resist the pressure of the tool. During grinding also the steadies resist the pressure of the grinding-wheel. But this pressure is comparatively slight. The principal use of steadies, therefore, is to prevent chatter by absorbing vibrations, in the same way that a hand clasped on a bell will deaden its vibrations. This explains why they are employed when short pieces that are of large diameter relatively to length are supported by steadies, which is never done in the lathe. It also explains the necessity of employing a very large number of steadies for the support of long slender pieces—a long array crowded almost close together. A rough rule is to place them at distances apart equal to six times the diameter of the piece being ground; but they are often spaced more closely than this; and as the length of the work in proportion to its diameter increases, the necessity for and the utility of the rests becomes even more insistent. For supporting short stiff pieces the shape imparted to them matters less than when long slender pieces are being ground. In the first the work receives support from the centres adjacent. In the second the control of these centres is of much less value. In lathe work of a similar class, steadies also are multiplied, or a following steady is employed. But the latter is impracticable in grinding, in conjunction with the rapid traverse of wheel or work.

Since the function of a steady is to afford support to work at all stages of its treatment, its construction must be of an elastic character. It takes charge from the first rough grinding to the final reduction to finished size. An exception occurs in sizing steadies which are only used for very fine finish-grinding. But the ordinary rests have to accommodate themselves to the work as it becomes reduced without any preparatory necking or spot-turning. At first, therefore, they simply oppose lightly the pressure of the wheel by contact with the rough surfaces. Afterwards they accommodate themselves to the work as it is reduced.

Further, all grinding steadies are now designed to afford support in two directions: one at the rear, in opposition to the horizontal pressure of the grinding-wheel; the other at the bottom, to counteract the sag of the work in slender pieces, and the downward pressure of the wheel. These facts explain the reason why practically all steadies now make contact at the rear and below, and why the older steadies, which took a bearing only at the back, were unsatisfactory. It is clearly, too, an advantage when the steady embraces the lower part of the work very close to the wheel, where the downward pressure comes. But the contact should never be continuous between the extreme locations, as is often the practice in lathe steadies. The shoes are distinct and separate, with a space intervening. They may form portions of a single block, or, as is more usual, be wholly separate, and operated independently. Around these principles of design the greater number of steadies are now constructed.

If a comparison be made between the steadies illustrated here and those that were shown in an article published on page 111 of the issue of ENGINEERING of July 24, 1903, the differences which will be noticed are generally as follow:—The preference for larger arcs of contact between the shoes and the revolving work, the lessening use of springs in favour of what are termed "solid" rests, and the introduction of the automatically adjusting design. With reference to the first, the shoe may be in one piece, making contact in two places, with a clearance space cut out between; or, which seems preferable in all except small diameters, two shoes may be fitted, each with its own adjustment independent of that of the other. But whichever design is adopted, the contacts sometimes embrace one-third or more of the circumference of the work, one shoe being brought rather close up to the wheel, the other being located above the centre in opposition to the radial thrust of the wheel. Also, the contact of each shoe is often that of an arc instead of a mere flat surface, which affords only line contact.

These differences from older practice have been of an evolutionary character, having developed along with the more severe demands which have been made on grinding-machines, both in regard to their approach to higher degrees of accuracy and their increased production. With the growing employment of wide-face wheels and of coarser traverses, which have been remarked in these articles, the use of more efficient steady-rests has become imperative. The reason why the work is generally embraced over large arcs is, as has been already stated, to prevent or absorb vibrations, to eliminate the influence of chatter-marks that result from vibration, and to offer resistance to the thrust of the wheel both in the axial and in the vertical direction. None of the earlier rests fulfilled these functions satisfactorily; but heavy grinding was never done in the earlier days, and scarcely attempted, because true work, round and free from chatter-marks, could not have been produced on the light machines then available except by light cutting.

The wide shoes are also designed and proportioned to embrace and cover the irregularities of the rough surfaces of the work, the irregularities both of the first rough pieces and of those which are produced by vibrations. The lower shoe is also adjusted to spring the work upwards, for the reason to be noted directly, while the upper one simply opposes the horizontal pressure of the wheel. And thus the large area of the work which is embraced causes it to be supported as in a bearing, and the large area which is provided by each separate shoe prevents minute irregularities of movement. Obviously, the line contact of a narrow edge is liable to permit these irregularities to follow that edge, and these may be constantly perpetuated by the wheel.

With regard to the second fact, that of the increasing use of solid rests, this also is a result of the heavier grinding which is now done. The spring-rests are suitable for light articles, but are not the best for heavy duty, for which the rest must be rigid. A transitional form is the useful combination design to be employed either with or without the spring, in which design nuts can be tightened to take the elasticity out of the springs or stops be arranged to size finished pieces. It is rather difficult to reconcile the varied practice which now exists concerning the employment and the abandonment of springs. Their tendency seems to aggravate the vibration which has to be avoided. On the other hand, the elastic accommodation which they furnish to rough surfaces is an advantage. They are more suitable for light grinding than for heavy, and as the former has predominated until a recent period, that explains why the spring-supported shoes have retained their place. With the growth of heavy grinding, steadies of a more solid kind are required. Steadies of any types, like other elements of grinding-machines, should be massive and be well supported in order to absorb vibrations.

With reference to the automatic or self-adjusting steadies, these are few, as yet, and recent. The principle embodied is, that when long pieces are being reduced, the advantage of solid steadies shall not be sacrificed to spring adjustments. The designs make provision for feeding a row of steadies inwards by a predetermined amount, corresponding with the reduction of the work.

A minor change is seen in the materials that are used for the shoes. Wood formerly predominated. It is cheap, easily fitted and renewed. It divided favour with bronze. Steel was used for permanent service. Steel now is used increasingly, consequent on the heavier duty that is being demanded. Wood and brass wear rapidly, they retain grit, which scratches the work; steel does not do so, and steel is therefore necessary when permanent repetitive work is being done.

A back-rest used now on the Brown and Sharpe universal machines is shown by Fig. 337, on Plate XXXIII. In order to absorb vibrations effectually the body A is made very substantially. It is clamped on the bed by the opposition of the milled-head screw to the hook in the T-slot. The shoe B, which makes contact with the work in horizontal and vertical positions, is pivoted on trunnion-pins at *a*. Shoes to suit a range of sizes of finished work are provided. The shoes are free to take up positions which are controlled by the stop screws C and D, and regulated by the milled-heads E and F. The pivoting of the parts renders them susceptible to the actions of these screws. Thus the piece G is hinged at *b* to the body A, and the arm H is hinged to this, and rests on a roller pivoted on the stud *c*.

When making adjustments, the shoe B being hung on its trunnions, the screw C is turned back until the shoe clears the work, and the nut F is loosened, relieving pressure on the spring *d*. The screw D is run back. The screw E is now turned in its nut to make light pressure on the spring *e*. Then the screw C is turned until it presses on the heel of the pivoted shoe B, causing it to come in contact with the work at *f* and *g*. Holding the screw with one hand in gentle contact with the work, the screw D is turned carefully to make slight pressure on the body at *h*, the shoe being thus retained in contact with the work at *f* and *g*. Then the nut F is turned to put a slight pressure on the spring *d*. The tension on the springs *d* and *e* must be but slight—only enough to counteract the pressure of the wheel during the final cut. If the pressure is divided unequally the shoe will bear unequally at *f* and *g*. The function of D is to duplicate pieces. When it rests against its abutment at *h* the pressure of the shoe on the work is relieved. The adjustments of C and D remain untouched for duplication of work, C is readjusted only when the shoe wears, and D for delicate adjustments of diameter.

A Landis steady is shown by Fig. 338. It supports the work at two points—one at A being opposite the point of pressure of the wheel, the other at B underneath. Each is adjusted independently by a screw with a milled head, which has an abutment-stop to limit its movements, this stop acting when the work is ground to size. This is of especial value in duplicating work, the setting being unaltered, except when compensation has to be made for the wearing of the jaws. When the work is being changed, the front support is withdrawn bodily, being carried in a separate bracket which slides on the base, and is clamped with a screw C giving a large range of movement. The screw D

regulates the spring tension of the plunger. The arm E, which carries the lower shoe, has a large range of movement suitable for large and small diameters.

A steady by the Narragansett Machine Company, of Providence, R I., U.S.A., is illustrated in Figs. 339 and 340. The actual steady is in one piece, notched between the areas of contact. It is pivoted in vees in a shoe B, which terminates the holder, and is locked when set by a screw C pressing on it from above. The stem of the holder is adjusted along its barrel, with a screw D at the rear, fitting in a bush in the stem similarly to the fitting of a poppet-barrel. The cylinder pivots on a pin *a* below the rear end for the purpose of adjustment, and is clamped by the screw E above at the front. This bears on the screwed pin *b*, by which the stem is clamped after having been set. The clamping of the body to the table is by a pivoted washer F and its bolt.

Fig. 341 shows a steady by the Queen City Machine-Tool Company, of Cincinnati, Ohio, U.S.A. Clamping to the table is effected with a screw provided with a lever. Provision is made for a large range of diameters, first by the longitudinal range of the upper steady-holder effected by its screw, and second by providing three separate holes, in either of which the lower holder can be pivoted.

Figures immediately succeeding illustrate a series of steadies by the Churchill Machine Tool Company, Limited, of Manchester. Fig. 342 shows a type used on the firm's 6-in. plain machines. It embodies an automatic spring mechanism, which is included in some other forms of steadies illustrated later. Another feature which it possesses is that of accommodation to cover the diameters within the capacity of the machine from maximum to minimum.

The body of the steady is clamped to the table with a hook-bolt. The top block-holder A is provided with means for travelling it to cover maximum and minimum sizes. The position of the lower block-holder B is changed with the same object, by giving the choice of two holes, a lower and an upper one, to receive the pin around which it pivots. The minute adjustment of the block is effected by the screw C, enough pressure being applied to spring the shaft above the normal centre height by the amount necessary to give it the necessary rigidity whilst being ground. The effort of the work being operated upon to return to the normal centre height makes the readjustment of this screw unnecessary. The upper adjustable steady-block A is acted upon by the spring at D. The screw E feeds the block-holder A. After the screw E has been set it is locked in position. The screw F adjusts the tension of the spring D. The tension of the spring D is adjusted by the nuts G through the medium of the screw F. When a new piece of work is inserted in the machine, the spring D is compressed, and the nuts G are thereby forced away from contact with the screw E. The pressure of the spring feeds the block-holder forward as the work becomes reduced until the nuts G come again into contact with the screw E, acting as stops to prevent further reduction. Compensation is made for the wear of the block by feeding the screw E forwards, which does not affect the previous setting of the spring. It will be noticed that the screw C by which the bottom block is adjusted passes through a slot in the upper block-holder A, this arrangement being adopted to secure a central thrust.

The steady shown in Figs. 343 and 344 is in principle similar to that in Fig. 342, the chief difference being that the bottom block is made reversible to take maximum and minimum diameters—this instead of having separate pivot-holes. The upper block-holder has the range of adjustment, the spring contact, the dead stop, and the central-thrust screw to the lower block, as in Fig. 342.

Fig. 345 shows one of the standard Churchill solid steadies. Except in the absence of springs it resembles that shown in Fig. 342. It has a large capacity for adjustment longitudinally by the movement of the slotted holder with its screw, and vertically by the provision of three holes for the insertion of the pivot of the lower holder. The adjusting-screw is also located centrally, passing through the upper holder.

Figs. 346 to 348 show a standardised design of steady suitable for one of the smaller sizes of Churchill grinders—the 4-in. swing. The body is secured to the table by the bevelled plate and screw. The steady-shoe, which is a block of wood, as shown, or of bronze or steel, is held in a shoe A by means of the screw C, and is adjustable along a pivoted holder B, which is pivoted in the body and adjusted round the pivot by the screw D. The linear position of the shoe A which carries the block is set by the nut E.

A steady designed for dealing with large diameters is seen in Fig. 349, and is an interesting example of a rigid design, confined in a small space owing to limitations in the swing of the machine. A steady shown by Figs. 350 and 351 is specially designed for service on the automobile cam-shaft attachment, which was illustrated on page 51 and Plate III., of the present volume. This, also, is locked when set on the bearing, while the cams are being ground. The horizontal adjustment is effected by the screw A at the rear, with a lock-nut. The range of adjustment is that afforded by a slot in the body. Vertical adjustment is provided by the pivot *a* and the central screw B, in opposition to the short tightening-screw C. The upper steady D is adjusted and secured by the eye-bolt E, to receive which D is slotted. It is fulcrumed on the lower one at *b*.

Figs. 352 and 353 represent a peculiar form of steady designed specially for grinding rams of 2 ft. 8 in. diameter. Being of large dimensions, a body is made in two portions fitted to the table of the machine. The body A of the upper portion is gripped to the V'd edges with a clamp plate B. The adjustment of its shoe is effected by a screwed stud C with nuts for locking it. The body D of the lower portion rests and is slid upon the table there, and the shoe E is pulled into contact by the bolt F. This is sufficient, because the shoe is located beyond the centre.

For some classes of textile work, the steady shown in Figs. 354 and 355 has been designed by Messrs. Churchill. The amount to be ground off is so extremely small that the steady remains absolutely fixed after being set. It is also suitable for encircling a portion already ground while adjacent parts are being reduced. A clamping-plate and screw are employed to bind the body to the table. The holder A is pivoted in two rollers *a*, *a*, which can be moved freely in a capped parallel recess in the upper part of the body. The rollers *a*, *a*, which carry the pivot, are adjusted longitudinally by the end screw B without any spring insertion, and the arm is clamped by the upper screw C after the vertical setting has been effected by the screw D towards the front. This screw has a central thrust, and is clamped, when set, with a screw *b* through the split lugs. The wood blocks are attached to the holder with screws. The upper block is carried in a cap E held down with an eye-bolt. The cap can be drawn away from the bolt for the purpose of removing the work. It is fulcrumed, as seen, into the holder.

The automatic ball-feed shown by Fig. 356, is a link between the rigid or the spring design, and the later fully automatic designs, in which the steady is fed towards the work. In Fig. 356 the ball A, tending to move downwards in its inclined groove by gravity, presses the long arm of the pivoted top-holder B upwards as the work becomes reduced, so closing the steady at the other end on the reduced diameter. There is thus no readjustment of the rest after it has been once set. The body is clamped to the V'd edge of the table, and the shoe is adjusted longitudinally with the screwed stud C at the rear, provided with lock-nuts. The vertical adjustment is made with the abutment screw D at the front.

The latest development is that of simultaneous and automatic movement of a row of solid steadies, to avoid the individual setting by hand. A novel design of this kind, Figs. 357 and 358, has been introduced by Messrs. Churchill. It avoids the repeated resetting of the range of steadies as the work becomes reduced, by providing means for feeding them forward simultaneously as the grinding proceeds. Also it arrests the feed when the work is finished, even though the attendant neglects to stop the machine. This is accomplished primarily by the contact of an arm D with the rounded head W of a vertical standard attached to the bed, and which is struck by D during the passage of the moving work-table.

The cradle A of the steady, clamped on the slope of the work-table, terminates at the back in a jaw *a*, which embraces a bush *b*, together with a ratchet-wheel B and a cam C; these being in one piece, and being moved in unison through the action of the lever-arm D and a pawl F above, in engagement with the ratchet-wheel B. The stroke of the lever and the number of ratchet-teeth passed by the pawl are regulated by a set-screw G, which passes through the upper jaw *a*, and becomes a stop for a projection *c* on the pawl-lever D, and so regulates the stroke of the lever and the number of teeth taken by the pawl F. A spring plunger *d* in the lower jaw acts on the projection *c*, to return the lever D ready for the next stroke. One portion of the steady H is pivoted at one end to the cradle A by a stud *o*. A steel plate P is attached to the other end of the steady, to rest upon the cam C. The lower block-holder O is pivoted to H, either at *e* or *f*, in order to accommodate it to a range in diameters of work. The shaft R, being ground, is sprung upwards by the necessary amount to obtain rigidity by the bottom support O by means of an adjusting-screw S that passes through the body H and presses on the end of the support O. After the adjustment is made, the screw is locked by a pinching-screw *g*. The upper block-holder, the actual back-rest T, slides in the body H, and is adjusted radially by a screw U, which is locked with a pinching-screw.

The automatic action will now be readily understood. When the work-table is nearly at the end of its travel, and the plate P is resting on the smallest radius of the cam C, the pawl-lever D meets the rounded part W on the pillar, and is pushed inwards in the direction of the grinding-wheel Y. This movement causes the pawl F to turn the ratchet-wheel B through one or more teeth, depending on the setting. The cam C, turning with it, lifts the body H. The back-rest T therefore moves towards the work R by an amount which corresponds with the forward movement of the grinding-wheel Y. In this way the reduction in diameter of the work is compensated for. The operation is repeated at each stroke of the table, when the pawl-lever D meets the face W on the pillar. The bottom support O requires no further adjustment, because the work is sprung by the pressure of the screw S, and the reduction in diameter is compensated by an equivalent return of the work to its natural position.

The automatic arrest of the feed is effected by cutting away a few teeth from the ratchet at a point which corresponds with the top lift of the cam C. The pawl F will then slip on the ratchet B without turning it, and the feed of the steady ceases. After the work is taken out, the cam, with its parts, is returned to its correct position by turning the ratchet-wheel B by hand at the extension-part Z.

It will be seen that the feed adjustments all take place on the upper steady-block which is pivoted at *o*, and that the block is supported on the cam, which is operated by the ratchet-wheel and pawl at each reversal of the table, harmonising with the feed of the grinding-wheel. The lift of the cam is designed to feed the upper steady-block to the work by the amount to which the grinding-wheel is fed forward. That is, for a given number of teeth passed on the automatic wheel-feed, a corresponding number of teeth will be passed on the ratchet which operates the cam. When the cam has lifted the block to its maximum height, the ratchet ceases to operate, for which the blank space mentioned is provided on the ratchet-wheel. To set for a first piece of work, the cam is brought to its highest position, so that the cam sizes all succeeding pieces without any interference with the adjusting-screws.

Fig. 359, on Plate XXXIII., shows the application of the automatic feed to a row of steadies. A key-grooved shaft A is required, and one cam for each steady that is fitted. The single-ratchet mechanism operates them all through the medium of the shaft. In this figure the ratchet-lever is seen at D and the fixed projection at W.

In a patent by the Norton Grinding Company, illustrated by Fig. 360, provision is also made by which a series of steady-rests are all controlled by the two end ones, and are simultaneously and automatically checked at a predetermined point, causing the grinding to cease. In this arrangement the part A of the rest which carries the shoe is mounted in a body B, which slides on the vertical face of the bed, to which it is clamped with a pivoted gib C, to facilitate rapid dismantling. The rear end of the holder A has a spherical surface to receive the radial pressure of a screw D for the purpose of adjustment. But the adjustment is made through a pinion E, which is carried by the screw D, and engages with a rack F, through which simultaneous adjustments are imparted to all

the rests in the row. Each rest is supported on a roller G, which moves on the bed of the machine, and which is adjusted vertically by means of a screw H, also operated by a pinion J and a rack K, similarly to the radial adjustment.

The two racks F and K are connected at one end by a slotted yoke, not indicated, through pivoted heads on the racks. A spring attached to this yoke at one end, and to the back-rest at the opposite end of the machine, connects the latter with the yoke. The yoke is moved along a slotted guide by a looped handle. As all the rests are connected by the racks, they are all controlled by the end ones next the machine centres, where there is no bending of the work. To check the feed movement at any desired point, the pinions E and J have each a hub, on which a split ring L is clamped to the hub and screw. The ring M has a projection with an adjusting-screw N, which engages a stop O on the back-rest, and thus prevents movement of the rests beyond the point predetermined.

THE INSTITUTION OF NAVAL ARCHITECTS.

IN our issue of last week we gave an account of the earlier proceedings of the meeting of the Institution of Naval Architects, held in the hall of the Royal Society of Arts on the 12th and 13th inst. We now proceed with our report of the subsequent meetings of the session.

THE MARINE DIESEL ENGINE AND ITS POSSIBILITIES.

The first paper taken at the evening meeting of the 12th inst. was entitled "A Brief Summary of the Present Position of the Marine Diesel Engine and its Possibilities." It was read in abstract by the author, Engineer-Lieut.-Commander W. P. Sillince, R.N. (Ret.). We reproduce this paper in full on page 388 of the present issue.

The discussion was opened by Mr. J. T. Milton, who stated that two years ago he had read before the Institution a paper having a similar title. He (the speaker) had experience with mercantile ships only, and could not discuss the application of Diesel engines to warships and submarines. The author, on the other hand, had given more attention to their application to warships, and he (the speaker) was pleased to note that there was some scope for the engines in warships other than submarines. In one part of his paper the author had stated that there must be some substantial advantages to justify the change from steam to Diesel engines. In the case of warships one great advantage was that the staff on board ship was enormously reduced when Diesel engines were fitted. Steamers required a large number of stokers if the boilers were coal-fired, and even when the boilers were oil-fuel fired they needed a larger staff than ships of the same power propelled by Diesel engines. It was most important to reduce the number of the personnel, and that was especially desirable in the case of destroyers. The author's table showing the applicability of the Diesel engine to large powers contained very interesting figures, with which he (the speaker) quite agreed. In this table the author had only dealt with double-acting cylinders, but with four lines of shafting and single-acting engines the required powers were obtainable by using a different type of engine. He (the speaker) here referred to the Junker type, and such an "opposed piston" type had been experimented upon by Messrs. Doxford, who had found it a very reliable one indeed. With it one could obtain the power required on four lines of shafting. In the case of the engine No. 4 in the author's table, the working height above the crank-shaft was given as 21 ft.; that was a height of about seven times the stroke. In the opposed piston type there was a very much less total height of the engine. The "opposed piston" type had the advantage that in each cylinder there were two pistons, and in each cylinder the speed was 2000 ft. per minute on two pistons. The engine built by Messrs. Doxford had not reached finality yet, but it was very reliable and very secure. Instead of going in for excessive pressures to a maximum of 750 lb. per sq. in. and a mean pressure of 120 lb., it was wiser to maintain a pressure of 500 lb. per sq. in. and use larger cylinders. One condition in the Diesel engine was that it had to be made strong enough to resist that high pressure. Messrs. Sulzer obtained a mean pressure of 115 lb. A most successful engine was that built by Messrs. Burmeister and Wain; the Suecia was fitted with engines of this make, in which the maximum pressure was 500 lb., and the mean pressure only 88 lb. per sq. in. Striving after economy, Messrs. Doxford worked to the above-named maximum pressure of 750 lb., and a mean pressure of 120 lb., which figures were higher than those of any other makers. The speaker then added that the proportion between the maximum loads and the loads on the engine should be lessened, and this could be done.

The most important part of the author's paper was to the effect that with very few exceptions the marine Diesel engine had been evolved and developed on the Continent, where the largest experience had been gained and the most progress made. The author's expectation that matters in regard to Diesel engines, as far as Great Britain was concerned, would soon be righted, he (the speaker) hoped would come true. The author had also advocated complete collaboration between the various departments of one firm and interchange of ideas between builders and users, and this, according to the speaker, was most desirable. He, however, feared that as far as the matter concerned British builders and users a frank interchange of ideas would not result. A large number of statements had been made of late as to what the Government was going to do on the subject of applied science, but he, nevertheless, feared that the Government would do nothing; and as far as interchange of ideas went, if this came about, it would be due to the action of the builders themselves. If all the makers combined together and investigated jointly the various problems, the Diesel-engine industry would be greatly benefited thereby. In the Institution information was exchanged between members, and he felt sure that each member generally received more than he gave, and the same would apply were the Diesel-engine builders to act collectively, as had been suggested by the author. If the belief were held that any firm had a monopoly of knowledge, this was certainly wrong, and matters in respect to the point aimed at should be facilitated by the fact that after the war every firm would have as much work as it could cope with.

The author had referred to the difficulties met with in regard to castings, and had mentioned "semi-steel," a cast iron containing a percentage of steel. In regard to cast iron, he (the speaker) was of opinion that engineers did not know much about it, whilst they could have known much more had they collaborated together. He (the speaker) had witnessed most marvellous tests carried out on cast iron in a Continental works; the material was hard and strong, it had withstood a large number of impact tests, and had a high tensile figure. The metal called "semi-steel" was made in crucibles, and not in a cupola, for in this latter the steel added would take up carbon. This question of the metal was one on which information was wanted, and if six firms tried to reach a solution independently one of the other, the expenditure was six-fold, whilst one could do the work and hand over the results to the others.

The author had referred to an important point—namely, the trouble which arose through fuel-valves acting badly and the manner in which the fuel was introduced into the cylinders. He (the speaker) could corroborate this, for to his knowledge an economy of 10 per cent. had in one instance been realised by a change in the fuel-valves. He also agreed with the author in advocating a complete interchange of ideas between the builders and the users of Diesel engines.

Mr. W. T. Batho, who followed, found the points put forward by the author in regard to the possibilities of the Diesel engine on warships most interesting. But he did not agree with him when he said that not much progress had been achieved during the last eighteen months. The difficulties which surrounded the large types of Diesel engines had been solved, and the speaker mentioned the fact that a 2000-brake horse-power cylinder had been thoroughly tested, showing that 10,000 to 12,000 brake horse-power could be put on one shaft. This cylinder was 39.4 in. in diameter for a stroke of 43.3 in., two-cycle, single-acting; this size would be suitable for a battleship. The working height was 20 ft., and there would be sufficient space in the engine-room to allow of dismantling. The weight was 165 lb. per brake horse-power and the load on the piston was 350 tons. When the engine was first run, few difficulties were encountered; the only trouble was with lubrication, but this was quickly overcome. The engine had been thoroughly tested in running for 13 hours at 1000 brake horse-power, 6 hours at 2000, and 2 hours at 2100 brake horse-power. The fuel consumption at full load had been 0.44 lb. per brake-horse-power hour. There had been no mechanical difficulty. When the engine was dismantled every separate part was found to be in perfect working order. High-speed engines of 400 to 500 horse-power per cylinder were to-day a possibility, weighing about 66 lb. per brake horse-power. It was a mistake to cut down the weight. All the troubles in Diesel engines could be overcome, and it had been a mistake at first to design them on the lines followed for steam-engines.

Mr. C. H. Wingfield, speaking with reference to Mr. Milton's remarks as regards cast iron, said that cast iron stood fatigue if the stresses were all on the same side, always exerted in the same direction. The direction of stress should never be reversed. Cast-iron piston-rings might be compressed together and afterwards show a good spring. Mr. Milton here stated that the tests he had witnessed on the Continent had been reversed.

Mr. B. P. Fielden, who followed, gave particulars of two ships similar in construction, one fitted with a quadruple-expansion engine burning coal, and the other with a four-cycle Diesel engine. The latter was able to carry 600 tons more cargo, owing to the saving in weight of fuel and water. An advantage was that in the case of a Diesel-engined ship there were no steam losses when the ship was lying idle; less men also were required, and the maintenance of full speed was not influenced by the men being adversely affected in hot weather. There were also less radiation losses. The possibilities of the Diesel engine were mostly of a commercial nature; and, as regarded consumption, when the fuel bill in a steamship was 6d., the corresponding figure for a motor-ship was 2d.

Mr. G. Windeler mentioned that in his works the draughtsmen frequently went into the shops to help the workmen out of any difficulty they might meet, and thus any defect in details of design was brought home to the draughtsman. In regard to the actual running of the engines, difficulties frequently arose through lack of experience on the part of the men who attended the engines. The Diesel engine was a comparatively simple one when it was understood, although it might seem complex to a man who had not had much to do with it. Mistakes had also been made by making one detail part to have several functions, as, when a failure occurred, it was very difficult to trace the failure to its right source. Difficulties largely occurred through the water-spaces getting clogged up; there should be ample cleaning spaces, and there should also be regulations dealing with periodical cleaning out. He contended that the research work in regard to cast iron had not all been done on the Continent. He had carried out such research work, and had found that cast iron having a tensile stress of 18 to 20 tons per sq. in., with a scleroscope hardness of 44, was good for cylinders and covers, the phosphorus in which should not exceed 0.2 per cent. The liners, however, could contain a fair amount of phosphorus. Some cast iron which was melted with about 30 per cent. of steel scrap in the cupola gave good test results. The study of micrographs for quality required much comparative knowledge and experience. It would be greatly desirable to exchange information for securing improvements, but he (the speaker) was afraid that in this country this was the last thing which makers wanted to do. Makers had been asked to develop a high-speed Diesel engine, and they found that objection had been raised against high speed on the ground that combustion could not be obtained at high speeds. But this problem had been tackled; high-speed engines had been built and they were working satisfactorily. There was sufficient capital and organisation in this country for doing all that was done on the Continent, but, unfortunately, British manufacturers were far too short-sighted to carry out investigations or to allow those who could to do so. If the combustion of the fuel in the cylinder was taken as an instance, it would be found that about as much was known about the point as about the Zeppelins, and when more was known many troubles would be overcome. The exhaust gases should be maintained as clean as possible, otherwise the gases would destroy the valves and other parts of the engine.

Commander Sillince, in his reply to the discus-

sion, said that the Junker type of engine gave artificially a stroke quite as long as the throw of a crank; this had advantages but also disadvantages. Personally, he believed, especially in the case of higher-power engines, in having a support between each crank and the next, and this was not possible in the case of the Junker engine, unless the particular advantages of that engine were suppressed. The reduction in the number of stokers required was a most important advantage of the motor-ship. It would have been interesting to add to his table the figures covering single-acting engines, and also those for the Junker type of engine, but he had limited himself to the tendency which ruled for very large units. Single-acting engines had been constructed experimentally of practically the same power as the larger units of double-acting engines. A lower maximum pressure for the same mean pressure was very effective, and it would be worth while to work on that line. He was not able to deal now with the points raised in regard to cast iron. The "semi-steel" he had seen had been made by adding steel turnings to the metal, run out of the crucible in the same way as nickel was added to molten steel. As regarded collaboration, there was no doubt that we were behind the times; the necessary information should be common property among the people who would be able to use it, thereby allowing them to meet foreign competitors. As to the lack of progress made during the last eighteen months, he believed that only one Continental firm had progressed during the time; manufacturers were generally busy in making engines on their standard sizes, and they were naturally making as many as they could whilst there was a good market. Mr. Wingfield's remarks on cast iron were interesting, and he (the author) found that we did not know much concerning that metal. Trust had to be reposed in the men who bought the pig-iron and in those who mixed the brands and produced the cast-iron parts. He thought that the Board of Trade might show some interest in the Diesel engine for marine and other purposes, and when matters commenced to settle down after the war the British Colonies would look to this country to supply them instead of foreign builders. It was the duty of British manufacturers to satisfy their demands thoroughly.

On the motion of the President, the author was awarded a hearty vote of thanks for his contribution.

On the Co-Ordination of Propeller Results.

The next paper taken was one "On the Co-Ordination of Propeller Results," by Mr. J. Denholm Young, Wh. Sc.; it was read in abstract by the author, who explained that his object had been to make more rapid and convenient the use of the constants, efficiency values, blade-width values, and other data already established by Mr. Froude, Mr. D. W. Taylor and others, and to compare actual results of large propellers with these values, with a view to obtaining guidance in the solution of propeller problems under varying conditions. He also explained his construction and use of a logarithmic field diagram, and showed how it aided the rapid solution of any variations of the problems to be met with, without further calculations.

Note on Maximum Propulsive Efficiency of Screw Propellers.

The paper having the above title, by Mr. T. C. Tobin, was then taken as read.

Mr. S. Barnaby, in a few words, said he appreciated the value of Mr. Young's paper and the work he had carried out from the experiments in the Froude and Taylor tanks, with the addition of full-size experiments. In this most interesting work he had followed Captain Dyson in the latter's work in the United States. Mr. Tobin co-ordinated the results of experiments obtained in air and water, and tried to deduce from these the limiting propeller efficiency possible. He (the speaker) added that he had also worked on the same lines.

Mr. W. J. Luke, who followed, added his appreciation to that of the former speaker, and welcomed Mr. Young's paper from the point of view of the information it gave from actual ship trials. The results were cast in a new form, and if they were carefully followed up, more engineers would be encouraged to analyse propeller results than had been the case in the past. When actual ship trials were fortunate, no examination was carried out, but when they happened not to be successful an examination of the conditions that obtained followed. It was necessary also to look into the conditions which obtained when the trials were satisfactory, with a view to gain experience; to ascertain why ships varied so much in propeller capacity as they did. Therefore every attempt that was made to set out the model experiments in an attractive way was to be recommended and was welcome.

Mr. Young thanked the meeting for the way in which his paper had been received, and agreed with the statement that the steam-trial records should be thoroughly gauged. It was, of course, cheaper to work from the tanks, but figures from actual trials added to the tank experiments would give valuable data. He was grateful to Mr. Barnaby, who was our greatest authority on propellers, for his appreciation.

Both authors, on the motion of the Chairman, were cordially thanked for their contributions.

Sub-Division of Merchant Vessels.

At the morning meeting of Thursday, the 13th inst., three papers on this subject were discussed together. The first was on "Sub-Division of Merchant Vessels: Reports of the Bulkhead Committee, 1912-15," by Sir Archibald Denny, Bart., reproduced on page 372 of this issue; the second, on "Strength of Water-Tight Bulkheads," by Mr. J. Foster King, given in full on page 372; and the third, on "Some Effects of the Bulkhead Committee's Report in Practice," by Mr. A. T. Wall, which we hope to reproduce later.

The discussion was opened by Professor J. J. Welch, who confined his remarks mainly to the paper by Mr A. T. Wall. He, however, noted that Mr. Foster King had correctly remarked that it was impossible to use the strain-indicators to the best advantage. One of Mr. King's experiments was to ascertain the extent to which the bulkhead plating was working with the stiffener, and he (the speaker) showed on the blackboard the application of two strain-indicators, one on the flange and one on the web of the ⊐ bar; the readings obtained under different heads of water stress gave the zero stress and the position of the neutral axis. The results showed that as the head increased so the neutral axis moved more and more towards the plating, until under full heads the position of the neutral axis agreed with the calculated neutral axis. He also agreed with Mr. King that he was fortunate in being able to see the experiment at Messrs. Doxford; the bulkhead used was deeper than the lower portion of the bulkhead of the Committee, and the experiment showed the soundness of the Committee's work.

Mr. Wall's paper gave some very interesting particulars, showing the effect of the Bulkhead Committee's rules in special cases, and also made some suggestions as to methods of using the information in the report for design purposes, and as to possible simplification. As to the first part, the illustrations clearly showed that in general the new requirements were in excess of those hitherto asked for, with consequent increased chances of safety after accidents, and Mr. Wall further showed that, like most other desirable things, this had to be paid for. The price, though substantial in some cases, did not seem excessive, and the effect of the rules on design would be good, inducing larger freeboard ratios in the smaller types in order to get reasonable sub-divisions.

The author noted that the initial work to be carried out before the floodable lengths could be lifted was quite appreciable, as it undoubtedly was, but it was difficult to see how this could be altogether avoided if the spacing of bulkheads was to be arranged in accordance with the variants which must be considered in any logical system. If there was distinct variation of the new design from the standard form, an expert designer, from the information given in the Committee's report, could, without appreciable loss of time, assess the consequent effect on floodable lengths for all practical purposes of the design stage. Mr. Wall also pointed out that if alterations were introduced during the development of the design, such modifications might have an effect on the proposed bulkhead spacing or the draught. This was common experience, alteration in one element of design often entailing modifications in other particulars, and was not peculiar to sub-division details. The note on permeability of ends pointed out that by putting cargo below the bulkhead deck and passengers above, the bulkheads could be somewhat more widely spaced on the same draught; or, with the same spacing, the draught could be somewhat increased, as compared with a similar vessel with passengers berthed on deck. This seemed very reasonable, and certainly the passengers placed above deck would have no cause for complaint.

He (the speaker) was not aware that, as indicated by the author, the criterion of service was intended strictly to take into account the number of passengers, but rather to discriminate as to type of ship. The International Conference laid it down that the factor of sub-division should decrease in a regular and continuous manner as for given length. This decrease was to be regulated by a "criterion of service." It was easy to argue that any one of several factors, such as number of passengers carried in relation to length or tonnage, per cent. of volume devoted to cargo or to machinery, &c., should be looked upon as the dominant characteristic and adopted as the sole criterion of service. The question was carefully considered by the Bulkhead Committee, and it was decided to recommend a single criterion in which the several factors had one weight, and not one factor only. If number of passengers only had been taken, then, in the case cited by Mr. Wall, it would have been necessary to adopt different load-lines in the two cases.

The author had pointed out that a ship with a factor of sub-division of 0.5 was not what was known as a two-compartment ship throughout. On the average it was so, being a little in excess amidships and slightly in defect at the ends. This was well recognised by the International Conference and Bulkhead Committee, and the terms "one-compartment" and "two-compartment" vessels did not occur in their reports. In getting gradually increasing severity of sub-division with increase of length, the one-compartment type first merged into the two-compartment type amidships, and finally throughout. In any system it was difficult to avoid "steps" at certain points, and in some methods of sub-division a length of ship a foot more or less in the region stated critical length was accompanied by distinct difference in bulkhead requirements. Mr. Wall mentioned in this connection what he called an anomaly where the factor of sub-division was round about 0.5. To introduce a certain amount of flexibility in design, the International Conference recommended that where the factor was 0.5 or less it might be doubled to give the permissible length of two adjacent compartments. This permitted the use of a long in connection with a short compartment, the long one being necessarily therefore longer than the permissible length of one compartment. On ships having a greater factor than 0.5 it would be less safe to allow this flexibility. In the example given in the paper, closer agreement might be obtained by moving the machinery compartments somewhat further aft in the vessel governed by the permissible length of one compartment. As to the accuracy obtainable in practice, the report of the Bulkhead Committee clearly pointed out that even if methods of complete accuracy could be employed, the safety obtained could only be relative and conditional. It was obvious that on a particular voyage the permeability might differ materially from that assumed, so that accuracy in that sense was obviously not possible. But this factor of uncertainty was more or less common to all seagoing vessels, and having once fixed the standard of permeability, it seemed reasonable to say that a designer who adopted a form of ship which allowed of wider spacing of bulkheads with equal safety should be allowed to take advantage of this, and the more accurately this could be done in reason the better, so as to be fair between ship and ship.

As to the strength point mentioned by Mr. Wall, it appeared as though it was assumed that 4 per cent. of the longitudinal material would be saved by a decrease of 4 per cent. in the maximum bending moment near amidships. If this was so, he (the speaker) thought Mr. Wall would find that that was a distinct over-estimate of the possible saving. The author had suggested approximations which would allow the standard particulars to be recorded in more compact form, and he (the speaker), took it that every one would be glad if this were possible without sacrifice of accuracy. He assumed that freeboard ratios less than 0.2 were unlikely to be met with in future, and he (the speaker) was inclined to agree with him. But he also said, quite

correctly, that there were many vessels now in existance with 0 1 freeboard ratio (some indeed had less), and under existing circumstances, therefore, it was necessary that responsible officials and designers should have information respecting such low freeboards. The assumption was made in Fig. 17 that the alteration of floodable length for a 0.05 alteration of sheer ratio was independent of permeability and freeboard ratio, which might easily lead to an error in floodable length of about 1½ per cent. of the ship's length for an alteration of 0.1 sheer ratio. This might be a useful quantity to a designer at a certain critical point, and well worth a little extra trouble. In the simplified curves, no note was taken of the alteration in longitudinal position of centre of flotation of mean water plane with modification of freeboard ratio, nor of the variation of sectional area coefficient β with alteration of sheer ratio or freeboard ratio, details which were required when dealing with forms other than the standard. It was true that the author suggested that the comparison between new and standard forms should be made, not at the actual freeboard and sheer ratio of the new ship, but at some previously fixed-upon standard value; in that case certain percentages would need to be added to or subtracted from floodable lengths so obtained, to get these for the ship at her actual freeboard and sheer ratios, so that altogether he (the speaker) was not sanguine that much time would be saved in the process.

It was fully anticipated by the members of the Bulkhead Committee that auxiliary curves could be constructed in the different designing offices, from the information given in the report, to cover the usual range of freeboard ratio, sheer ratio, permeability and type of ship dealt with. In that case the elements of a new vessel could be readily compared with those of existing ships, and all necessary floodable length curves obtained with a near approach to accuracy. The author had shown what he had done in this direction so far as standard forms were concerned, and no doubt others were recording floodable length curves for their own special-type ships. Such accumulation of data would, as in other departments of design, reduce to a minimum the labour of fixing the position of bulkheads according to the Committee's recommendation.

Commander Boris, of the French Corps of Naval Architects, who followed, said he was very happy that the chances of the war had led him to come to the meeting. The fact that the Committee had been working in a humanitarian direction during the present war was a highly creditable one. It was significant that the Committee was most probably sitting during the week in May last at a time when the Lusitania was being sunk. Also that the man who was responsible for the sinking of that ship was the same one who had initiated the International Conference on Safety of Life at Sea. He (the speaker) was greatly interested in the classification which Sir Archibald Denny had made of various systems of sub-division. At this stage the speaker sketched on the blackboard a ship's section having a longitudinal bulkhead, and pointed out how from being dangerous in the centre line it had a varied efficiency, or gave no safety, according as it was moved towards the ship's side. In the matter of water-tight doors, he thought with Mr. Wall that the stringency of the rules would probably reduce their number. The matter reminded him of a French book on poetry which contained a chapter entitled "Poetical Licences," followed by the subject-matter which only stated "There are no poetical licences." He (the speaker) thought that a book on water-tight doors would simply state "There are no water-tight doors." He was very much interested in Mr. Foster King's paper, and thought that every naval constructor would find in it much to meditate upon and to take into account in design; the concluding sentence was an especially striking one.

The work of the International Conference was hard; it could not be final, and was bound to be complicated. Improvements were in a sense a simplification, and there was room for a large number of simplifications. Mr. Wall's paper was valuable as showing how simplifications were to be looked for and worked out. The term "criterion of service" was a term which had given the greatest trouble; the choice of a criterion was not easy, they had to give it up at the International Conference and leave the matter to other workers. The French delegates had had in mind a very simple criterion; it was no doubt too simple, as it could not be improved upon. It was the speed; the specified speed one could not be sure of when designing the ship; broad assumptions, which are permissible, should also be allowed in regard to the speed. Speed varied from, say, 10 knots for a cargo-boat to 25, 28, and prospectively 30 knots in the case of a liner; but it should be acknowledged that the grouping of all types along this co-ordinate was probably not the best. Engineer Rota's speed over length was perhaps better, or perhaps, again, length of engine-room to length of ship, or even, again, the coefficient of fineness, or perhaps a combination of all. Permeability was a factor necessarily taken into account during calculations, and it might be taken into account in the criterion.

Another point on which he (the speaker) was very keen, and this obtained generally on the Continent also, was the question of stability. He was always nervous in regard to stability. In this there were two factors, and Mr. Wall had pointed them out quite clearly; modulus was one factor, and reserve stability was another. The modulus generally increased by flooding, even during the flooding, whilst reserve stability was altogether different, and was even more important. Dynamic stability in flooding condition bore a great relation to the undamaged condition. Here the speaker drew a curve on the blackboard which fixed the longitudinal stability, and pointed out that a similar one could be drawn for the transversal stability. Accuracy in practice was the point they were all aiming at, but they had no illusion on the subject and some assumptions were bound to be approximate. Approximations might be made leading to simplification, and this would save time and money, resulting in an increase in the efficiency of shipbuilding, and in that of the whole nation. He favoured everything that made for simplification, even when this was surrounded with approximations. He was pleased to see in Mr. Wall's paper the suggestion of percentage curves; these would come in practice to allow designers to improve their types.

Mr. P. A. Hillhouse, who followed, said he found Mr. Wall had done a large amount of useful work. He personally welcomed all work which made the floodable length curves more simple; the author's curves would be most useful, but as printed they were rather difficult to read, and the different lines should be made in different thicknesses or in various colours. In regard to placing the passengers above the bulkhead deck, this might be possible when they were not in large numbers. With reference to the reduction of scantlings for reduced draught, he (the speaker) said this was covered by the Load-Line Committee.

Professor Abell, in the course of a few brief remarks, and with reference to Sir Archibald Denny's paper, said the author had referred to the instance of long ripping blows, but he (the speaker) did not wish to discuss the subject owing to lack of time. He also demurred to the same author's statement with reference to longitudinal bulkheads. In regard to Mr. Foster King's paper, he stated that in some parts of the ship lug connections were better than brackets, and stiffeners were mainly of use in the initial stages; and when the deflection was severe both the plating and stiffeners were in tension. There was a difference between the stiffeners when the water was on one side or the other. Mr. Wall had done a signal service to naval architects and to shipowners by his contribution, for he had brought out interesting factors. A main point in his paper was that the rules were framed upon a predetermined coefficient of permeability. He suggested that Mr. Wall should add curves or sets of tables for determining the floodable length.

Mr. Cole asked Mr. Foster King whether tests had been made with corrugated bulkheads, and whether in their case the $\frac{I}{y}$ basis would apply.

Sir Archibald Denny, in the course of a very brief reply, said, with regard to the criterion of service, he hoped the public would understand that the reference to it in his (Sir Archibald's) report was the expression of the Committee's opinion; the Board of Trade adopted the B curve, which was less severe. Difficulty commenced with ships of about 300 ft. length, when boiler arrangements were involved. In regard to safety, this could not be arrived at without paying for it. Mr. Wall's contribution proved to be exactly what the Committee had hoped for—namely, that designers would arrive at short cuts, that they would conceive methods of their own, using the Committee's curves. In regard to Professor Abell's remarks, he confessed to having suffered from a legal politico attitude, and his words had to be taken with some care and read both ways.

Mr. Foster King made some remarks on Mr. Wall's paper, and in replying to the discussion, thanked Professor Welch for his important addition to the data relating to the strength of bulkhead stiffeners. The lowering of the neutral axis of the stiffener under increasing load seemed to be quite consistent with the other indications, that in the early stages each stiffener acted as a beam, of which the bulkhead plating probably formed a comparatively unimportant member, and gradually passed to the diaphragm condition where the plating was the more important, and the whole material was in pure tension throughout the greater part of its length. Commander Boris had, with his usual acuteness, placed his finger upon the central lesson of the experiments by his quotation regarding certainty of movement in every bulkhead under load. Professor Abell, however, by indicating preference for one form of stiffener over another, under certain conditions, might perhaps help to obscure, to some extent, the practical application of that lesson. It was essential in the case of bulkheads having doors, and to which pipes, &c., were attached, to adopt the type of stiffening which would most effectually restrain deflection, and in all bulkheads to provide the arrangements having the least likelihood of rivet disturbance under load. Professor Abell's question as to the difference between stiffeners which were in and out of the water respectively was answered to some extent by the Board of Trade diagrams, where the curves of maximum deflection under both conditions had been shown. As the worst was the most important condition, the superior outside stiffening had not otherwise been enlarged upon in the paper, except by reference to the way in which the deeper flanged stiffeners held on, under large water pressures, where they were outside the tank, and to the fact that the practical collapse of similar stiffeners, where inside the tank, merely brought that part of the bulkhead into the same condition as the remainder, as part of the bulkhead diaphragm.

He was not aware that any test had been made of a corrugated bulkhead which was not supported by webs or other material, but Mr. Cole's question was, in any case, one which could only be properly answered by the Board of Trade, or by evidence that this or any other constructive method was at least as effective as the plane bulkhead diaphragms for which the Rules provided. Without in any way presuming to forecast the views of the Board, it was apparent that $\frac{I}{y}$ values equal to those standardised by the tables could easily be obtained from systems of corrugations, but the fact that plane bulkheads could and did remain effective in the sense that they were not liable to disruption, under conditions where the $\frac{I}{y}$ value of the stiffeners had become a matter of comparative unimportance, suggested experimental investigation in order to determine the value of $\frac{I}{y}$ as a measure of the capacity of corrugations to resist deformation.

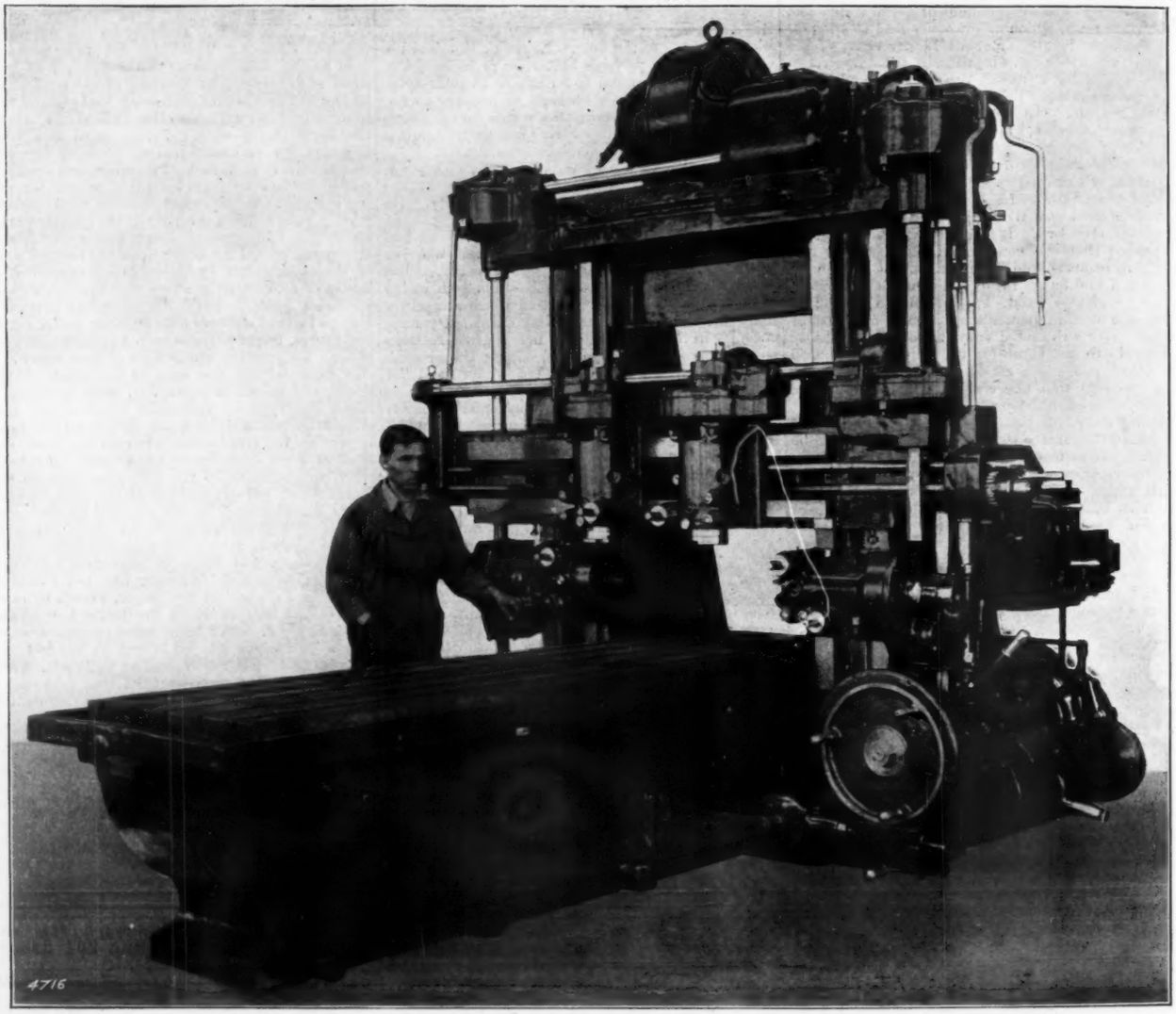
Mr. Wall said he was pleased with the reception accorded to his paper. When writing it he had feared that it might be taken as a superfluous criticism of the Bulkhead Committee's work; he was very glad, however, that it had not been looked at in that light. Professor Welch made a number of criticisms of the approximate method given, which appeared to show that he had not really got away from the mathematical accuracy that he had in his mind when he was setting out the curves of floodable lengths as given in the reports. The method shown in the paper was admittedly approximate, and, of course, there would be errors in its application. The question really hinged upon theoretical and practical accuracy. Many things could be worked out on paper very closely; but in practice a number of matters crept in to destroy all that had been done, and many assumptions made were not realised.

With regard to the criterion of service, it was quite evident from the discussion that a great difference of opinion existed on the subject, and since a number of different suggestions had been

FOUR-SPINDLE MILLING-MACHINE.

CONSTRUCTED BY THE INGERSOLL MILLING-MACHINE COMPANY, ENGINEERS, ROCKFORD, ILLINOIS, U.S.A.

(*For Description, see opposite Page.*)

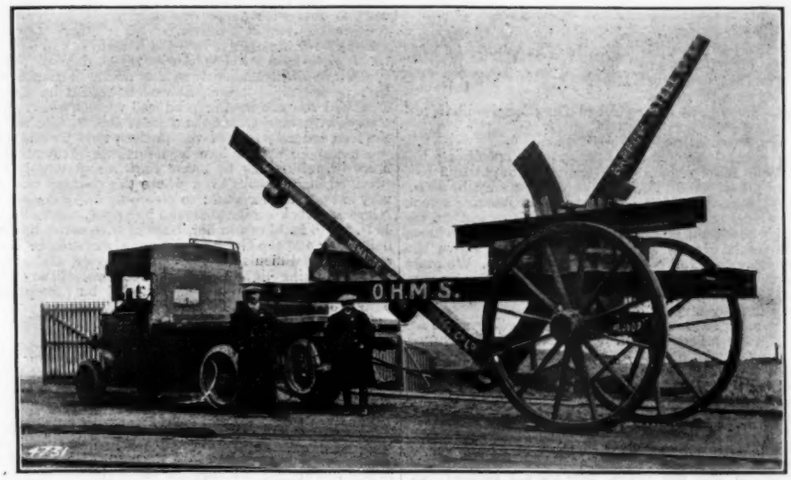


put forward in regard to it the speaker would add one that had occurred to him—namely, that the criterion of service should be taken as the ratio between the number of passengers and the displacement of the ship. Professor Welch had remarked that the Committee had realised that a 0.5 factor of subdivision would necessarily give a two-compartment ship, but Sir Archibald Denny, in his paper, had stated that the Committee had adopted the recommendation of the 1890-91 Committee—*i.e.*, that Channel steamers should be two-compartment vessels, and had therefore applied to them a factor of subdivision of 0.5. No doubt this had caused it to be generally understood that a 0.5 factor actually gave a two-compartment ship. (Sir Archibald here remarked that they were practically the same.) Professor Welch had observed that there was always a certain amount of trial and error in design, and this was quite true; but, nevertheless, if short cuts could be taken without undue sacrifice of accuracy they would always be welcomed, and the work of designers would be correspondingly reduced. Professor Welch and Mr. Foster King had both referred to the question of the weight saved by the reduction in draught, and had queried the figure of 4 per cent. given in the paper. There was no doubt that this figure was high, and probably the value would be about one-third of that given. Professor Welch had remarked that accurate floodable length curves would still be necessary to determine the spacing of bulkheads in ships of small freeboard ratios, but, generally speaking, it was possible to determine by inspection whether a ship could still retain a small freeboard ratio without going into detail. Professor Welch had also raised one or two other points in regard to the approximate method. He had said that the variation of floodable length would not be equal for equal increments of sheer ratio, but that, of course, would have to be accepted as being insufficiently accurate. In regard to the alteration of floodable length with variation of the centre of flotation of the mean water-plane in the standard form, this might easily be embodied in the approximate method. The variation of the sectional area coefficient with sheer ratio and freeboard ratio—although the speaker did not clearly understand Professor Welch's criticisms—was automatically allowed for in the approximate method.

Commander Boris had spoken of the number of water-tight doors tending to decrease on account of the introduction of the new Rules, but, as far as the limited experience of the speaker had gone, there had always been an increase. This was shown in Case I. in the paper, in which the ship, built before the new Rules were enforced, had five water-tight doors, and the new one had no less than eighteen. It was interesting to learn that Commander Boris considered the Rules complicated, and that he looked forward to simplifications being made in them.

Mr. Hillhouse had very properly pointed out that when the Rules first came into force they were very difficult to use, but that after some experience they became easier. The fact still remained, however, that they were complicated, and even when made easier by constant use there was still a certain amount of difficulty which could not be overcome. With regard to the same speaker's remarks about the passengers above the bulkhead deck, in the course of which he had mentioned that with a large number of third-class and steerage passengers it was necessary to put them below the bulkhead deck, the speaker quite realised this, and in the paper it was mentioned that the arrangement of keeping them all above the bulkhead deck was not always practicable. Mr. Hillhouse, and, later, Mr. Foster King, referred to the point that the reduction of the scantlings for reduced draught was covered by the Load-Line Committee. It was, however, only proper to point out that the Load-Line Rules were

TRANSPORTING A STERN-FRAME.



not yet in operation, and probably would not be for some time; so that in the meantime it was pertinent to inquire what attitude the classification societies would take up in regard to this matter. Professor Abell had made a very important point in asking for stepped curves or sets of tables for determining the floodable length. There were, no doubt, great advantages to be obtained by these means, as the designer could get his results within the limits of the steps, and then small alterations could be carried out without making the vessel fall outside these limits; his work would thus be simplified. That, of course, was a method very commonly used by the registration societies. Sir Archibald Denny had referred to his experience with Channel steamers of about 300 ft. long, and this was also the experience of the speaker. One boiler-room with a vessel of that length would have to be very large, and two were unnecessary, whereas in a boat 350 ft. long the boiler-power was greater, and two boiler-rooms would be needed; the sub-division would therefore be easier. Sir Archibald Denny also said that the standard form gave the most bulkheads, and that was good enough for the designer to work on. But if this were the case, Professor Welch's criticism about a variation of 1½ per cent. in the floodable length—which error, he said, would take place in the approximate method—was rather beside the point, because in going from the standard form to the ship form it was quite possible to get variations as great as 10 per cent. in the floodable length in certain positions, and 5 per cent. was quite common.

On the motion of the Chairman, the three authors were awarded a cordial vote of thanks for their contributions.

(To be continued.)

FOUR-SPINDLE MILLING-MACHINE.

THE illustration on the opposite page is reproduced from a photograph of a heavy planer-type milling-machine designed and constructed by the Ingersoll Milling-Machine Company, of Rockford, Illinois, U.S.A., for which firm Messrs. Burton, Griffiths and Co., of 1, 2, and 3, Ludgate-square, Ludgate-hill, E.C., are the British agents. Machines of this type are especially suitable for the gang milling of motor-car engine cylinders and crank-cases, but they are capable of giving very rapid production on all kinds of work which has to be machined on three surfaces at right angles, and have many advantages over planing-machines.

As will be seen, the machine has four spindles, two of which are vertical and are carried on saddles on an adjustable cross-rail, while the other two are horizontal and are mounted on the housings. The bed is of heavy box section, with double strengthening ribs inside, and is provided with strong lugs for the holding-down bolts. Its length is 1½ times that of the table, which has a total length of 9 ft., giving a working surface 8 ft. long; the difference of 1 ft. is accounted for by 6-in. oil-pockets at each end. The width of the working surface is 2 ft. 6 in., and it will take work 2 ft. high; tee-slots cut from the solid and pin-holes are provided for fixing the work or the jigs. The table runs on flat slides and is operated by the well-known Sellers skew drive. The housings, which are bolted and dowelled to the bed, are of box section with internal bracing ribs. They are 14 in. wide on the face and 28 in. deep at the bottom. The tops of the housings are connected by a casting, on which the motor is mounted if electric driving is employed, and this casting also carries the gearing for driving the spindles; 20 horse-power is required for driving the machine illustrated. The housings also carry a cross-rail 14 in. wide on the face and 7 in. deep from back to front, on which the saddles for the vertical spindles are mounted. The cross-rail is extended on the left-hand side, so that one of the saddles can traverse the whole width of the table, the other saddle then being left stationary at the extreme left of the cross-rail. A power up-and-down feed is provided for the cross-rail, and it can also be adjusted by power or by hand. The transverse feed of the saddles on the cross-rail is obtained by the screws, clearly shown in the photograph, which can be operated by hand or power; they can be fitted with micrometer collars for accurate adjustment if necessary. The horizontal saddles on the housings have a power feed, and can also be adjusted by hand by means of a rack and pinion. These saddles are counterbalanced by weights suspended inside the housings and attached to the saddles by means of wire ropes passing over sheaves at the top of the housings. They may, however, be mounted on the cross-rail, and adjusted with that by hand or power. This arrangement is convenient when it is desired to use the machine with cutters mounted on an arbor. It is often employed for finishing the end of a long piece with a slabbing cutter, using the vertical feed of the cross-rail for this purpose.

All the spindles, which are 3½ in. in diameter at the largest part of the taper, are of hammered open-hearth steel, and run in phosphor-bronze taper bearings, in which provision is made for taking up the wear. Each spindle is carried in a quill, with which a 6-in. adjustment can be obtained by a rack and pinion; a scale graduated in 64ths of an inch is provided to facilitate setting. The cutters usually employed are of the facing type, and in solid cutting they may be used up to 10 in. in diameter; if the cut is broken up, 12-in. cutters can be used. They are driven by the standard Ingersoll method, in which the shank is merely used for centring, and the drive is transmitted by a radial key fitting in a slot in the end of the spindle. The cutters are held in place by a nut on the shank. On these machines a cutter 9 in. in diameter will remove 8 cub. in. of ordinary cast iron per minute in regular work, though as much as 10 cub. in. can be removed in the same time. The method of driving the spindles will be clear from an inspection of the illustration, and it will be noticed that all the gears employed for this purpose are completely enclosed. It should, however, be mentioned that the two vertical spindles and either of the horizontal spindles can be thrown out of action by means of clutches. Eight spindle speeds, ranging from 15 to 120 revolutions per minute, are provided, four changes being obtained directly by the gear-box mounted on the casting connecting the housings, and the remainder by a pair of intermediate gears; the two handles used for varying the speeds can be seen in the top right-hand corner of the illustration. The feeds for the table, spindles, and cross-rail are obtained from the gear-box seen on the right-hand side of the illustration at the ground-level; all are reversible and are independent of the spindle speeds. Six feeds are obtained by shifting a tumbler-lever on the gear-box, and these can all be altered by means of a pair of interchangeable gears operated by another lever, so that twelve feeds are provided in all. The table feed ranges from 0.6 in. to 13 in. per minute, and the cross-feed for the vertical spindles from 0.45 in. to 10 in. per minute; the cross-rail feed can be varied from $\frac{1}{16}$ in. to $\frac{3}{8}$ in. per minute. Under ordinary conditions the table feed and cross-feed cannot be operated simultaneously, but means are provided to enable this to be done if necessary, as may be the case when a number of small bosses have to be finished. Hand and power quick adjustments are also provided for all these movements, the former being operated by a hand-wheel on the left-hand side of the gear-box, and the latter by a friction-clutch and gears inside the box; the power quick adjustment moves the table at about 21 ft. per minute.

The standard sizes of these machines are made with tables 24 in., 30 in., 36 in., 42 in., and 48 in. wide, and ranging from 8 ft. to 16 ft. long in 2-ft. steps; they can be supplied with any combination of saddles. Special saddles, with two or three spindles each, and swivelling heads for angular work, can be furnished. Similar machines are also made with fixed cross-rails for use on manufacturing work in which single pieces have to be machined in large quantities.

TRANSPORTING A STERN-FRAME.

RECENTLY the Barrow Hematite Steel Company, Limited, of Barrow-in-Furness, Lancashire, undertook to supply two stern-frames for vessels under construction by Messrs. Earle's Shipbuilding Company, of Hull. On account of their large size, each frame was made in two parts, suitably scarfed together. The smaller parts were despatched by rail in the usual way, but the two larger portions had to be conveyed by some other means, their dimensions being greater than could be dealt with by the railway companies. In the ordinary course, such large and awkward castings would be forwarded by sea, but in this case the difficulty of arranging for a suitable vessel within reasonable time proved insurmountable. It was therefore decided to send the castings from Barrow to Hull by road, and a suitable route had to be chosen, on which the road surface was sufficiently good and the hills not too steep. In making the selection, care had to be taken to see that any bridges to be crossed were strong enough to carry the weights, and also to avoid bridges over the road, which, especially in the case of the older towns and villages, are usually too low to allow for the passage of articles of the size in question. With these points in view, a course was traced out, and inspected by a preliminary run over it by motor-car, the distance being 154 miles.

Each casting was carried separately, and the above illustration, taken from a photograph, shows clearly the simple and effective way in which it was arranged for transport. The motive power was provided by a 6-ton steam motor wagon, which was connected, for the time being, to a large trailer by two steel girders, between which the castings were slung just high enough to clear any irregularities in the roads, the distance between the trailer and the rear wagon wheels being 20 ft.

An important part of the business of the Barrow Hematite Steel Company consists of ships' structural castings, examples of which, weighing up to over 30 tons each, have been turned out complete in every respect, the foundries being provided with all the necessary plant, including engineering shops and annealing furnaces capable of dealing with the largest castings of this description.

The transport contract in this case was placed with Mr. E. S. Hodgson, of Manchester, under whose able supervision it was expeditiously and satisfactorily completed.

NEW SHIPBUILDING YARDS IN SPAIN.—We read in the *Revista Minera, Metalúrgica y de Ingeniería* that steps are being taken in Spain for extending ship construction. A company is being formed in Bilbao for establishing a new yard on the Nervión, and if the scheme succeeds, there will be four shipbuilding yards at Bilbao. In the Asturias, a scheme is on foot for putting down a yard at San Esteban de Pravia, or at Avilés. At Barcelona, a yard is being fitted up on the shore of Casa Antúnez mostly for the construction of large wood sailing ships fitted with an auxiliary boiler.

THE INSTITUTE OF METALS.—Our attention has been called to the statement in our report of the discussion on the paper entitled "The Electrolytic Method of Preventing Corrosion," on page 319 *ante*, to the effect that "'. . . the captain adopted the Cumberland method . . .' The matter, we are informed, was dealt with by the Engine Department of the White Star Line, for which Mr. W. J. Willett Bruce is responsible. The ship referred to was not the Celtic, but the Laurentic. In regard to Mr. Cumberland's paper, reproduced on page 314 *ante*, the system is only fitted to the main condensers of the Britannic, and not, as stated, to that ship's boilers, condensers, fresh and salt-water tanks.

SUB-DIVISION OF MERCHANT VESSELS: REPORTS OF THE BULKHEAD COMMITTEE, 1912-15.*

By Sir ARCHIBALD DENNY, Bart., LL.D.,
Vice-President.

THE Second Report of the Bulkhead Committee,† of which I had the honour to be Chairman, was signed on August 6, 1915. It deals with home-trade passenger vessels, and all cargo vessels, to the exclusion of sailing vessels, steam-launches, motor-boats, steam fish-carriers, tugs, steam-lighters, dredgers, hoppers, &c. Some of these might require attention in respect of subdivision in the event of their carrying passengers, but this is left to the authorities.

The classes reported upon were thus:—(*a*) All passenger steamers having steam 2 certificates, whether limited or unlimited. (*b*) Passenger vessels having steam 3, 4, and 5 certificates. (*c*) All cargo vessels, whether foreign-going or home trade. Steam vessels holding 2, 3, 4, and 5‡ certificates, while divided officially into four classes, and by the Committee into five, have no sharp lines of demarcation; some vessels holding all the certificates, and many holding three of them. They vary greatly in size and in type, some of the smaller ones being little larger than steam-launches. It was therefore decided to deal with them in a broad and general manner, noting that there would require to be exemption in some cases, where the literal application of the proposals would be unreasonable or unnecessary. In other special cases the present practice might be in advance of that recommended generally, in which case the higher standard should be adhered to; in fact, as stated in the report:—"Our recommendations, in short, are intended for the ordinary cases, which constitute the majority of those under consideration; and it will be for the authorities to decide on the modification necessary in special cases, including cases where they may recommend modification in excess of the above-mentioned minima." Subject to certain specific modifications mentioned later, it was recommended that the First Report§ should apply to all home-trade passenger vessels.

When the steam 2 vessels were examined, it was generally noted that little or no difference could be seen between the larger of these vessels and vessels of the same size in the foreign-going class. It seemed, therefore, reasonable to apply the First Report sub-division *simpliciter* to this class. Included in steam 2, however, there is one distinct type to which no parallel is found in foreign-going vessels, and that is cross-channel passenger steamers, which the 1890-91 Committee considered should be two-compartment vessels whatever their length. We concurred with the intention of that Committee, and therefore applied a factor of sub-division of 0.5 to them; noting only that if they were less than 300 ft. in length, it might not always be possible to apply the factor throughout the whole length, and leaving it to the authorities to decide.

Limited steam 2 and steam 3, 4, and 5 vessels merge into one another more or less, and as steam 3, 4, and 5 vessels are almost exclusively engaged in the transport of passengers, and frequently carry large numbers, it seemed natural to treat them in a similar manner to the cross-channel vessels. The curves B and C (see Report) were therefore departed from entirely, and for steam 3, 4, and 5 vessels those over 300 ft. in length were required to be sub-divided, using the factor 0.5, both fore and aft. Vessels over 200 ft. and not over 300 ft. in length are to be sub-divided by a factor of 0.5 from the stem to the after machinery bulkhead, abaft that by a factor of 1. In vessels over 100 ft. and not over 200 ft., neither the combined length of the two forward compartments nor the length of any other compartment must exceed the floodable length. Vessels not over 100 ft. in length shall have peak and machinery bulkheads.

As to details, I shall deal with water-tight doors later when referring to the reports as a whole, but in regard to openings in the shell, side-scuttles, &c., for home-trade vessels, very stringent rules are suggested. The other items similar to those in the First Report are the entering in official logs of the periodical operation and inspection of water-tight doors, &c., which must, however, be somewhat different from those applicable to foreign-going steamers. I shall not deal at all with the construction and strength of bulkheads, as my colleague, Mr. Foster King, is reading a paper on that subject.

Professor Welch's paper of last year‖ dealt very fully with the First Report, first from the historical point of view, and then in regard to the value and extent of sub-division recommended, and the proposed rules for ascertaining the position of bulkheads. He purposely excluded from the scope of his paper the construction and scantlings of bulkheads, the fitting of water-tight doors, the protection of openings in the sides and bottom, and pumping and piping. I had hoped that my colleague, Mr. Andrew Laing, who had charge of the Sub-Committee on Water-Tight Doors and Pumping and Piping, would have contributed a paper on his work, and I still hope he may find time to do so; but I shall make some general remarks which have reference to both reports. Since the First Report was issued a few amendments in details seemed advisable, and these will be found referred to in paragraph 197. I suppose, in view of the tremendous scope of our inquiry, that other amendments will be suggested, but I think the general system will be found reasonable.

GENERAL REMARKS ON BOTH REPORTS.

In regard to the systems of sub-division, I personally place them in the following order of suitability for ordinary merchant vessels:—

1. Plain transverse bulkheads.
2. Water-tight decks.
3. Inner skin, as distinguished from longitudinal vertical sub-division.
4. Longitudinal vertical sub-division.

The Committee had some difficulty in specifying the conditions under which a water-tight deck might be fitted, and they were finally forced to say that it must be above the load water-line; but I can quite well imagine a deck fitted wholly or partially below the water-line, and yet the stability condition of the vessel to be such that no harm would result even if the vessel was pierced above the water-tight deck and below the load water-line. We must trust to administrative action and time to clear up that point, and many others on which we could only give general guidance.

As to inner skins and their depth, several formulæ for their depth were considered. The formula finally adopted is, I think, a very reasonable compromise between a fixed depth and a depth proportional to the size of the vessel. For direct collision at right angles to the skin or violent explosion an inner skin might be of little value, but for the long grazing blow it might be invaluable.

If the utility of any of the above four systems of sub-division, or a combination of them, is proved at sea by damage to compartments, then, if the damage is not sufficient to sink the vessel, longitudinal vertical sub-division may cause such a list as to render navigation difficult; while, on the other hand, a water-tight deck fitted as recommended is likely to affect the stability favourably. Further, if the extent of the damage is such as to render ultimate abandonment necessary, then the chance of launching small boats successfully may be greater if longitudinal vertical sub-division does not form part of the scheme. For the long ripping blow, such as sank the Titanic, longitudinal vertical sub-division is attractive; but the Committee proposed that it should be shown that the vessel would not heel over so as to submerge the margin line when the rip is equal to the floodable length. The result of the loss of the Empress of Ireland was to draw our attention to the fact that danger lurked in side bunkers, even if they are not water-tight. These bunkers cannot always be avoided, but similar regulations are suggested against serious list, and are embodied in the First Report. Under certain circumstances there is no doubt that longitudinal vertical sub-division is a source of security, and any reasonable list due to one side being flooded can be corrected, given time, by flooding the opposite side. This the Committee considered should be done positively by some suitable means, and not by cross-connections working automatically. In oil-fired vessels, where side bunkers can be, and probably for other reasons would be, cross connected, this consideration might disappear.

Water-Tight Doors.—The first question to be decided was, should these doors be permitted in the machinery space? There was never any doubt that they should be forbidden in cargo holds, or cargo 'tween decks below the load water-line. Much evidence was taken on this point, and from mercantile sources this evidence was so unanimous that for trading vessels it was inadvisable, if not impossible, to dispense with them, that it was decided to permit them in machinery spaces under stringent provisions for safety, these provisions becoming practically more and more stringent as the number of souls on board became greater, culminating in doors released from a central station. I need not trouble you with the details of construction which are the best modern practice. The Committee went further in the direction of stiffening the conditions than the International Conference, and it is a question in my mind whether the effect of that stiffening will not be to cause doors to be more and more avoided. In the case of cross-channel and steam 3, 4 and 5 vessels the opinion was expressed that doors might be dispensed with, but, if fitted, they should be of the centrally released type.

Openings in Sides.—Here, again, advanced recommendations are made, but in this case the efficiency of these recommendations depends to a very large extent on the care taken by those on board. There seems little doubt that a contributory cause to the loss of the Empress of Ireland, at least to the shortness of time which elapsed before sinking, was the fact that ports were open.

Pumping and Piping.—Very many schemes for fitting what really amounted to salvage gear were considered, but the Committee came to the conclusion that it was only a matter of degree, and that efficient sub-division, combined with a pumping plant sufficient to deal with leakage into an intact compartment after damage, was all that should be called for, leaving it to individual owners to add to this by fitting salvage gear—either water-pumping or compressed air, with air-tight decks—should they so desire. At the request of Lord Mersey, the question of air-tight decks and air compressing plant was specially considered, and estimates of cost were even got out, but the above was the conclusion arrived at, and the plant recommended, which is not greatly in excess of the maximum required by the classification societies, will be found in Chapter IX., First Report. In the Second Report, modifications for home-trade vessels of certain classes will be found in paragraph 229, page 8.

Cargo Steamers, both Home and Foreign.—The Committee's opinion will be found expressed in paragraphs 237, 238, and 239, page 9, Second Report. It was thought better to leave these vessels to the classification societies, suggesting, however, that bulkheads called for by their rules should not be omitted, except where these are entirely unavoidable, having regard to the service of the vessel. The International Conference declined emphatically to deal with cargo vessels internationally. After the war is over an interesting paper might be written dealing with the mass of information which will no doubt be available as to the behaviour of vessels damaged, either sufficiently or insufficiently to sink them. I do not think that designers of merchant vessels should be severely criticised for not having produced vessels which would always withstand torpedo and mine attack, especially as the tremendous power of the modern torpedo and mine was not and could not have been foreseen by them. It is, however, interesting to know that many vessels have survived such attacks even where the damage was of a very extensive character; to give only one example, the Nigretia struck a mine abaft the fore peak, and had a hole 40 ft. by 16 ft. blown in her, but she was saved by No. 2 bulkhead; and the Germans did not always realise that it is somewhat difficult to sink an oil-carrier, especially if she is running light—*vide* the Artemis. Many other cases might no doubt be mentioned, but it is perhaps better to wait until the war is over.

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* Paper read at the Institution of Naval Architects, April 13, 1916.

† See ENGINEERING, vol. c., page 399.

‡ For particulars of trading limits of these vessels, see Second Report of the Bulkhead Committee, page 4.

§ See ENGINEERING, vol. xcix., page 49.

‖ Transactions of the Institution of Naval Architects, vol. lvii, page 1. See ENGINEERING, vol. xcix, pages 339, 364.

STRENGTH OF WATER-TIGHT BULKHEADS.*

By J. FOSTER KING, Member of Council.

THE problem of the necessary structural strength for water-tight bulkheads has received much attention and many theoretical answers, yet the variations to be found in practice appear to contradict these answers as flatly as one bulkhead contradicts another in scantlings, and as plainly as experience controverts assertions as to the weakness of bulkheads in general.

The importance of bulkhead strength in relation to sub-division is too obvious for comment, and the Bulkhead Committee naturally devoted a very great deal of time and work in trying to find satisfactory bases for the strength of partitions, which have recently been made obligatory in all passenger ships. This particular branch of the Committee's work was placed in the hands of a sub-committee, of which Dr. Thearle was originally chairman, and there is no member of this Institute but must feel sadness in the thought that he has not been spared to complete the labours he had so ably initiated.

The facts which the author is permitted to place before you are those which have been ascertained by the Bulkhead Committee on behalf of the Government, so that they and the deductions therefrom embodied in the Committee's Report have all the weight and value which attaches to unbiassed research by such authority; any other deductions or suggestions which may be made in the paper are the author's, and have no more significance than attaches itself thereto.

The possibility of testing ordinary bulkheads on board ship was seriously considered, and some public-spirited owners actually contemplated filling holds with water, but close touch with practical difficulties led to the dismissal of the idea. The Committee decided that simple vertical stiffening is the best form for which to legislate, and as this is now ordinary standard of practice for the bulkheads of deep tanks, it was considered that a good deal of information might be readily obtained from tests of such tanks. Through the generosity of the Clan Line, Messrs. Robert Duncan and Co., Port Glasgow, and Messrs. Palmers, of Jarrow, the Committee were enabled to carry out tests on three deep-tank bulkheads constructed on these lines; and, no doubt, if the work could have been done systematically, and extended over a sufficient number of cases, it might have been possible to establish a safe standard for bulkhead stiffeners by these means alone.

It had to be recognised, however, that the details of construction required for tank service are superior to those employed in ordinary water-tight bulkheads, so that the tests could not furnish information as to the sufficiency of the latter, nor could they be pushed to the point where reconstruction might become necessary. The Committee felt that, apart from considerations of time and trespass upon private generosity, they would fail in public duty if they did not try to find out not only that which is safe, but, what is much more important, that which is unsafe. Such information could only be obtained from bulkheads built purely for experimental purposes, and Sir Archibald Denny did a great service to the nation when he so represented the case to the Board of Trade that the Government authorised the construction of experimental bulkheads, which are fully described in the Bulkhead Report.

Following upon the experiments on the deep tank and experimental bulkheads, and the compilation of scantling tables, the Committee fell heir to a piece of good fortune—thanks to the enterprise and public spirit of Messrs. Doxford, of Sunderland, and Messrs. the Hogg-Car Construction Company—by means of which they were able to carry out a further series of experiments upon a bulkhead constructed to the requirements of the new tables, and to test their deductions while their work was still in progress.

Before proceeding with the details of the experiments and other relevant matter, it seems desirable to consider the methods of observing bulkheads under test. Common practice is to measure deflections with a 2-ft. rule from stout cord or spun yarn stretched from side to side of the ship; a step in advance replaces spun yarn with piano wire under strain, but neither method provides a suffi-

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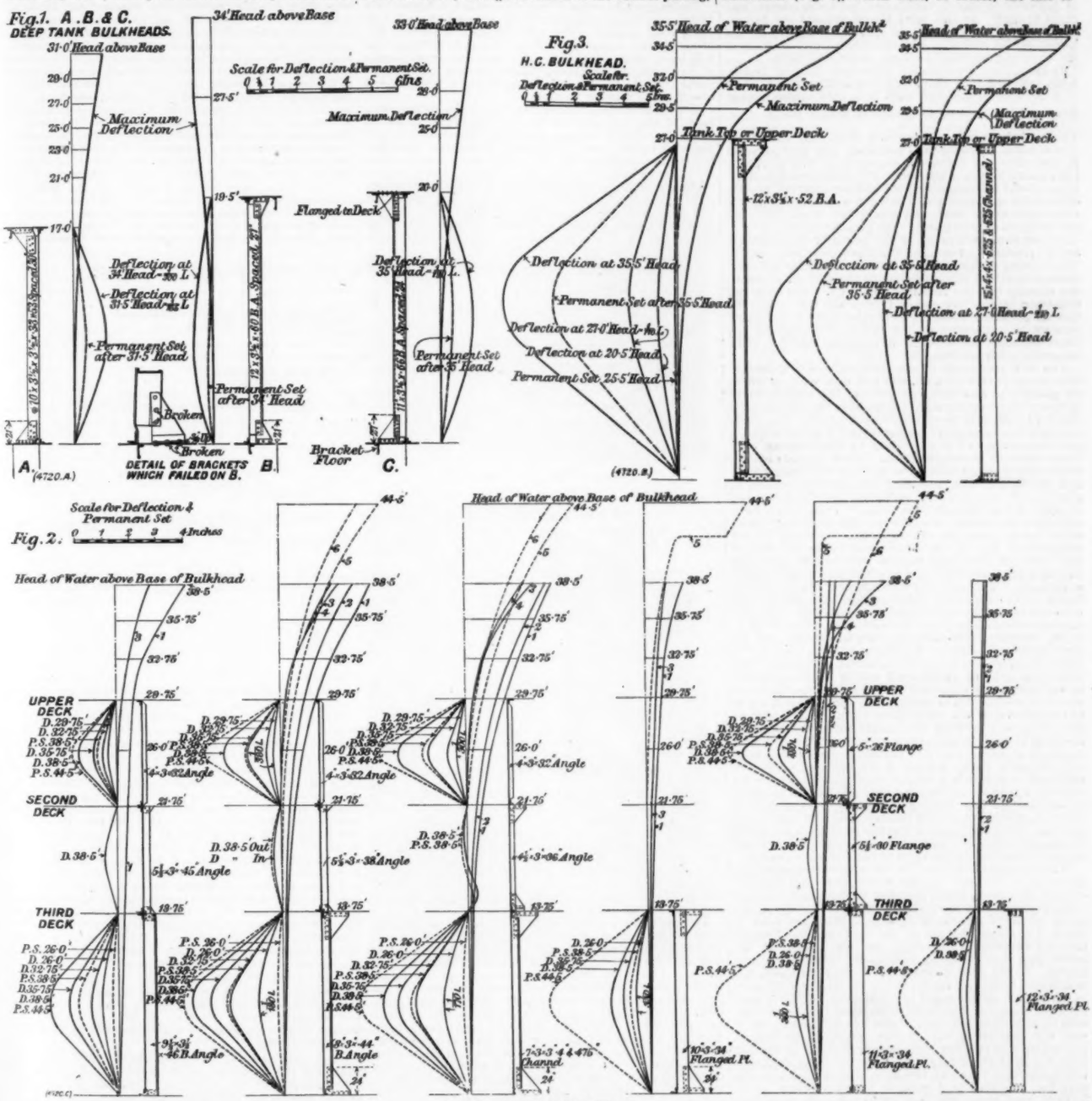
* Paper read at the Institution of Naval Architects, April 13, 1916.

ciently accurate basis for recording the exact form of deflections. The records of the Government experimental bulkhead (described as B.T. bulkhead in the rest of the paper) were taken at each stiffener from vertical piano wires, which passed through close-fitting collars on the upper deck and tank top plating, and from which 56-lb. weights were suspended, so that the datum lines were accurate. The measurements, which numbered thousands, were taken by the use of minutely subdivided steel rules, by lads who were specially trained to measure to the second decimal place, and they deserve congratulations for the speed and comparative accuracy with which the work was done, often under very adverse conditions. The weather was generally bad, and when the experiments subjected the structure to great strain, the fear of breaking rivets and the effects of leakage made it practically impossible for all the measurements to be accurate. With this method, it would probably make for greater speed and accuracy if the deflections were simply marked on thin boards instead of being measured; there could then be no after-doubts as to the position of decimal points. The records of the second experimental bulkhead (which is referred to as "D" bulkhead in the rest of the paper) were made on vertical boards placed in line with the stiffeners, on which the datum lines and subsequent deflections therefrom were scrieved by means of steel points guided by square blocks run along the edge of the stiffener. In this case the subsequent recording suffered a little from failure to foresee that the bulkhead would move outwards, through extension of the bottom plating, and that the supports of the cofferdam would "give" under the weight of water. The latter movement threw the scrieve-boards slightly out of the vertical, but the defect was at once observed, and the necessary correction obtained by means of vertical piano wires carrying weights, as in the B.T. test. Even with this small handicap, the scrieve-boards proved themselves to be the quickest, most complete, and definite method of recording in the author's experience, and there would seem to be little difficulty in so arranging them in future as to maintain a constant distance from the heel of the bulkhead margin angles, and avoid the effects of change in height and position of the bulkhead. Turning now to the actual experiments, it may be explained that the deflections had been drawn down more than once by others, but it appeared to be desirable to the author that they should be again recorded independently by himself. This has been done, and the act has been useful, although it would not have been attempted had the amount of labour been realised. The "D" bulkhead lines (Fig. 3), which were, of course, the last to



B. T. BULKHEADS.

1. CURVE OF MAXIMUM DEFLECTION HOLD STIFFENERS (INSIDE).
2. DITTO DITTO DITTO (OUTSIDE).
3. DITTO DITTO UPPER 'TWEEN DECK STIFFENERS (INSIDE).
4. CURVE OF MAXIMUM DEFLECTION, UPPER 'TWEEN DECK STIFFENERS (OUTSIDE).
5. CURVE OF MAXIMUM PERMANENT SET HOLD STIFFENERS.
6. DITTO DITTO UPPER 'TWEEN DECK STIFFENERS.

be tackled, showed definitely that each deflection forms part of a triangle having the straight bulkhead for a base, and its apex at or about mid-depth, the curved part being tangential to the sides of the triangle, and becoming aborter as deflection increased. This discovery had an obvious relationship to previous difficulty in trying to persuade battens to pass fairly through spots. Its application to the other bulkheads was found to eliminate nearly all difficulties and doubts as to the correct measurement, and gave greatly increased confidence in the correctness of the plotted deflection lines.

The results of the tests on the deep-tank bulkheads are

recorded in Fig. 1 over the letters A, B, and C. A bulkhead had previously been in service for some eight years, and there was an initial permanent set of about $\frac{5}{16}$ on the stiffeners selected as giving the fairest record of pressure effect. The stiffeners are 10-in. Z bars, spaced 30 in. apart, and the margin angles are single bars, single riveted, so that the construction is practically that of an ordinary bulkhead. The tests were carried to a head of 14 ft. above the tank when they were stopped on account of probable damage to ventilators, hatchway covers, and other fittings. At this head the permanent set had increased to $\frac{7}{16}$; the deflection was equal to $\frac{1}{10\frac{1}{2}}$ of the length of the stiffener, and the riveting and caulking of the bulkhead remained perfectly sound and tight.

B and C are two similar bulkheads, B being 19.5 ft. deep, stiffened with 12-in. bulb angles 27 in. apart, while C is 20 ft. deep, stiffened with 11-in bulb angles, spaced 24 in. apart, the $\frac{I}{Y}$ value of the stiffeners being alike.

The brackets in B are particularly small, but the deflection is much less than in C bulkhead, and does not seem to have increased during the passage from 8 ft. to 14.5 ft. head above the top of the tank. The conditions as to flexibility of end attachments of the stiffeners are not greatly different in each case, yet C pursued the normal course of deflections under increasing heads, and B did not; the reason is not easy to guess. The greatest deflection on C bulkhead amounted to $\frac{1}{11\frac{1}{2}}$ of the length of the stiffener, and all riveting and caulking remained quite satisfactory. The riveting of three bottom brackets in B near the starboard side of the ship gave out in the fashion shown in the sketch, but the remainder held on. The bulkhead deflection at the fore end of B tank was not measured, but the structure certainly did better than B bulkhead, because, as is thought, all the stiffeners overlapped the lower boundary angle instead of stopping well clear of it, as on the bulkhead observed.

The B.T. bulkheads formed the walls of a cofferdam 25 ft. long, 29 ft. 9 in. high, and 7 ft. 6 in. wide, in which an endeavour was made to embody the conditions of ordinary ship construction, except that the brackets on the hold stiffeners were larger than usual. The workmanship represented ordinary shipyard work on ordinary ship bulkheads, and it was tested by hose pressure only before the tests were commenced. Each type of stiffener that experience suggested as being likely was represented, and the effect of such necessary variations in practice, as placing stiffeners, caulking, and margin angles inside and outside, were subjected to trial. Deflections were measured at regular intervals as the tank was being filled, but only the more important are recorded on the diagrams in Fig. 2. At 25 ft. head above the base of the bulkhead two sharp reports were heard, but filling was continued up to 26 ft., when complete measurements were taken. The tank was then emptied, examined, and found to be in perfect order, so that the reports were probably caused by local buckles blowing out. The permanent set was taken, and the tank again filled to 26 ft. head. A fresh set of measurements was taken, and the tank afterwards allowed to remain at this level for 16 hours, when a third set of measurements was taken. The water dropped 3 in. in the tank during the 16 hours, but it was thought that external evidence justified the belief that this was not due to leakage from the tank so much as to the stop-valve not being quite tight. There was no such difference between the second and third measurements as to draw serious attention to the element of time as affecting deflection. The curves shown for this head must be fairly correct records of the effect of subjecting the lower stiffeners to a head of water 12.25 ft. above the third deck, and the ratios of maximum deflection to length of stiffener at this head, given opposite to each hold stiffener, should form a fair indication of their respective stiffness. It is unfortunate that the position of the lower 'tween deck stiffeners between the millstones of upper and nether deflections render them of little practical value.

When the tank was filled to the upper deck there was some slight leakage, mostly where the margin angles crossed each other, at the points of change from inside to outside of tank, but the bulkhead was clearly satisfactory at its intended maximum pressure. With the head of water 3 ft. above the top of the bulkhead, the leakage had not increased appreciably, but the plating at the lower part was distinctly corrugated between the stiffeners. As the head of water was further increased, the deflections increased more rapidly on all the stiffeners, except on the three-flanged hold stiffeners, as will be seen from the curves of maximum deflections. It was evident that leakage from the deck angles was increasing, but it was not possible to tell by how much, on account of heavy rain and overflow from the stand-pipe. It was not until the head was nearly 6 ft. above the upper deck that two rivets were heard to break, so that it might be said that the bulkhead held good as a safety device up to 35.75 ft. head above the base, or 25 per cent. more load than full-tank condition. The pressure as it was being slowly increased until it was 8.75 ft. above the top of the tank was accompanied by the noise of an occasional breaking rivet, and an increase in leakage from the deck angles. The caulking of the plating held out satisfactorily up to 8 ft. head, when a short piece gave out, and the bulkhead began to make creaking noises. At 8.75 ft. head, or 38.5 ft. above base, it was decided to make another complete set of measurements, but this was accompanied by a fusillade of breaking rivets and the busting away of the lower end of the third bulb angle stiffener from the left-hand side, so that the lower bulkhead, as originally built, may be said to have definitely failed at a load more than a third greater than full-tank condition, but the upper 'tween stiffeners had successfully carried a load more than three times that due to water up to the top of the bulkhead.

The permanent set was considerable, and there was evidence that most of the stiffeners had begun to fall away from their work, except in the case of the deep flanged hold stiffeners, but the chief disturbance consisted in the pulling away of the brackets of the smaller stiffeners from the deck-plating. The maximum deflection of the lower plating between the stiffeners seems to have occurred at 35.75 ft. head, and at greater heads the plating tended to straighten again. The permanent set after 38.5 ft. head seems to average 0.025 in.

Preliminary to a second test, all buckled stiffeners were faired, and flanged brackets having increased rivet area were fitted instead of the ordinary plain brackets. The brackets were taken off one 8-in. bulb angle stiffener, and a 3½ by 3½ reverse angle fitted for more than three-fourths of its length. A bracketed stiffener in the lower 'tween decks was removed, and a larger angle without end attachments fitted in its place.

When under test, it was found that the rivet connections of the heel-brackets to tank top began to leak at an early stage in filling, probably on account of new material having been introduced. Before the tank was full the new stiffener on the lower 'tween-decks, on the outside, was being forced away at its ends, and it became necessary to shore up the ends of the stiffener to prevent it stripping the end rivets. With water 6 ft. above the top of the tank it was seen that the 8-in. bulb angle with the reverse angle was trying to force its lower end through the plating. With 9 ft. above the tank general leakage from the deck angles was increasing, the caulking was being started where these angles were inside, and the upper 'tween-deck stiffeners were becoming sources of leakage.

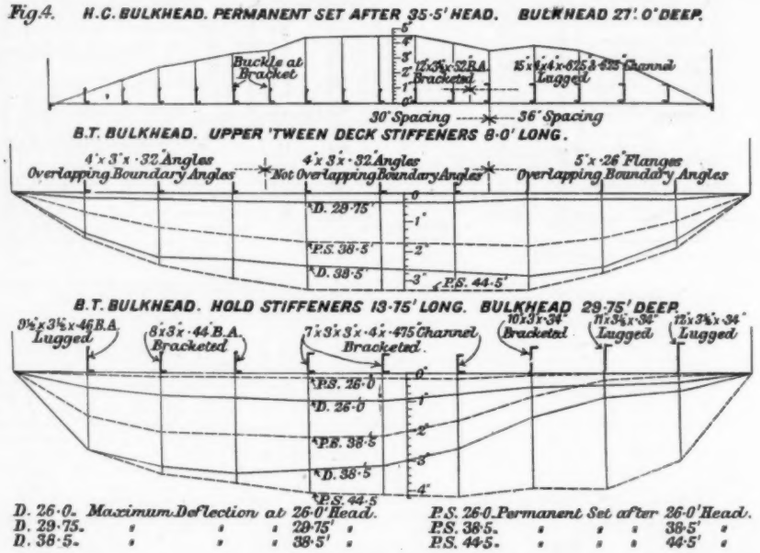
When there was 10 ft. of water above the bulkhead, or 4 ft. more than in the first test, rivets began to break, and at 4 ft. above, or 14.75 ft. total head, the bulkhead in way of the flanged stiffeners inside the tank suddenly blew out to the same extent as in way of other stiffeners, but where those were outside the bulkhead held on. It was found possible to carry on until there was nearly 15 ft. of water in the stand-pipe, to the accompaniment of breaking rivets and increasing leakage, so as to be too great for the pumps to overcome.

To summarise the observed results, damage which produced leakage manifested itself chiefly in the attachments of the ends of the stiffeners, the brackets causing most and lug connections least disturbance. The practical effect of improving the bracket connections had apparently been to prolong moderate water-tightness in the bulkhead until the load on the lower stiffeners was 65 per cent. above that due to full-tank condition, and to show that the upper 'tween-deck bulkhead could carry fully 4½ times its intended load. Special attention should be given to the fact that the edges and butts of the plating were all single-riveted, and neither riveting nor caulking showed signs of distress, in spite of the deformation of the structure vertically and horizontally between the stiffeners. The form and uniformity of the final permanent sets show in interesting, if not conclusive, fashion the comparative unimportance of stiffness in relation to ultimate strength of bulkhead.

Although not next in chronological order, the review of practical results is now carried on to the "D" bulkhead, illustrated in Fig. 6, page 375, which formed one side of a cofferdam 45 ft. long and 27 ft. high at the centre, and which was built to represent as far as practicable a 20-ft. segment of a single-deck ship. Five stiffeners on one side were lugged and spaced 36 in. apart, the remainder were bracketed and spaced 30 in. apart, both being fitted in accordance with the table requirements of the Bulkhead Committee for a height of 26 ft. The tank as designed was straight on top but camber was subsequently introduced, hence the discrepancy of a foot between the proposed and actual length of stiffener. Single riveted boundary angles were fitted across the deck and down one side, the others being riveted with one row of water-tight pitch at the caulking edge, and an inner row at double that pitch at the heel.

The deflections (see Fig. 3) were taken at intervals as the tank was being filled up to 20 ft. 6 in. above the bottom; the tank was then emptied and the permanent set recorded. The tank was then filled to the top, or 27 ft. head; the deflections were recorded then and at intervals up to a head of 8.5 ft. above the top of the bulkhead. At 20.5 ft. and 34.5 ft. the permanent sets were directly recorded; at intermediate heads the water was lowered to 20.5 ft. and the deflections recorded, so that by taking differences it was possible to obtain a complete curve of permanent sets without emptying the tank. At full tank condition the maximum deflection on the bracketed stiffeners was $\frac{1}{11\frac{1}{2}}$, and that on the lugged stiffeners rather better than $\frac{1}{12\frac{1}{2}}$ of the length, the load being 10 per cent. in excess of the table standard. The maximum load was practically 75 per cent. over that due to designed full tank condition, and the bulkhead was thoroughly effective as a safety device. The chief evidence of strain was found on the bottom of the bottom brackets, and its nature is indicated by the detail in Fig. 5, but no rivets had broken. A curious contradiction of theoretical expectation is given by the fact that the greatest distress and deflection were found on the centre stiffener where the bottom bracket was rigidly held by the centre girder beneath it. The upper brackets were quite undisturbed, but lifted the deck beam to which they were connected 2⅜ in. at the middle, and left a permanent upward set of 1$\frac{1}{16}$. The bottom lugs of the lugged stiffeners were efficient during the tests, but after their completion it was found that many of the rivets in the heels of the lugs on the tank top were started.

Fig. 4. H.C. BULKHEAD. PERMANENT SET AFTER 35·5' HEAD. BULKHEAD 27'·0" DEEP.



D. 26·0. Maximum Deflection at 26·0' Head. *P.S. 26·0. Permanent Set after 26·0' Head.*
D. 29·75. " " " 29·75' " *P.S. 38·5. " " " 38·5' "*
D. 38·5. " " " 38·5' " *P.S. 44·5. " " " 44·5' "*

The caulking of the plating held out satisfactorily up to 8 ft. head, when a short piece gave out, and the bulkhead began to make creaking noises. At 8.75 ft. head, or 38.5 ft. above base, it was decided to make another complete set of measurements, but this was accompanied by a fusillade of breaking rivets and the busting away of the lower end of the third bulb angle stiffener from the left-hand side, so that the lower bulkhead, as originally built, may be said to have definitely failed at a load more than a third greater than full-tank condition, but the upper 'tween stiffeners had successfully carried a load more than three times that due to water up to the top of the bulkhead.

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With regard to the plating of the bulkheads, it was found that when the tank was full there was about ⅛ in. deflection at 30 in. and ¼ in. at 36 in. spacing up and down the bulkhead, and there was practically no permanent set. The riveting and caulking showed no signs of distress, and while there was some leakage, it became less after the first filling and did not increase much at the big heads; it was always unimportant, and would have been within the control of a hand-pump on board ship. The double-riveted boundary angle was not so sound and tight as the single-riveted bar, so that when large heads of water suggest the desirability of double riveting, there should be two complete rows of rivets.

It is only right to say that at this date it would have been impossible to give the foregoing details of the actual experiments and their results but for the very admirable and complete reports prepared by Messrs. Fowling and Cox, of Lloyd's Register, for the information of the Bulkhead Committee.

Upon such facts it was necessary to decide upon a basis for the structure of bulkheads which could be recommended to the Board of Trade as providing a proper margin of resistance, and would also fulfil in some measure the much higher aspiration of the Bulkhead Committee, that the stiffeners should not rely upon the diaphragm effect of the containing ring formed by the hull structure. There was much discussion in the first instance, as to the proportion of plating which is an effective part of the stiffener girder, the relationship of actual to theoretical deflections for fixed and supported beams, and as to the actual stress upon the material. Attempts were made at almost every test to derive information from strain meters, but the utmost care could not guard the instruments from shock and bad weather, or ensure safety in acceptance of their records, so that these had reluctantly to be put to one side. As discussion failed to solve unknowns which require many further experiments for solution, and as under similar conditions they should each have a practically constant relationship to the $\frac{I}{Y}$ of the stiffeners themselves, it

was finally agreed to adopt a comparative strength standard for their sizes. This was based upon the observed performances of the various types of stiffener under load, and has the practical effect of placing the strength required for unattached ends at twice that required for bracketed stiffeners, the ratio of lugged to unattached ends being placed at seven to six. The sizes of brackets and the rivet value of attachments were made proportional to the sizes of the stiffeners and values of the moments appropriate to the conditions of constraint indicated by the deflections. The bulkhead plating, as expressed in the various bulkheads under test, appeared to show that ordinary practice is safe, and was therefore adopted under the regularising influence of requirements expressed in terms of spacing of stiffeners and head of water. The sizes of stiffener in the tables represent a distinct advance upon ordinary practice, and it will be seen from the relationship which they hold to existing tables of sizes for deep tank stiffeners, and from the very satisfactory results of the "D" bulkhead tests, that the Committee have recommended, and the Government have adopted, a standard of construction which should be entirely effective in providing a large margin of strength.

When considering the question of a suitable standard it was strongly felt that one based upon the capacity of stiffeners to resist deflection would be exceedingly valuable, but the difficulties appeared to be so great that the idea was not brought to a practical issue. Looking back upon the discussion in the light of present examination of the available data, as it appears to be established that the function of the stiffeners on a bulkhead is not so much to provide ultimate strength as to restrict early deflection, it is very desirable that records should be kept of the behaviour of all stiffeners under test in the future, in order to provide data from which it may be possible to derive a stiffness basis which might be even more satisfactory than a strength basis.

The Committee had next to give consideration to the desirability of modifying the standard of strength for home-trade ships and the lighter classes of ship generally. Although it is proved that very light bulkheads can and do successfully contain water, it was naturally contended that a second strength standard might be impolitic as throwing doubt upon the first. It was agreed, however, that the margin in the first is so ample, and that the range from moderate deflection to destruction is so wide, that it would be unreasonable to make such a wide provision against emergencies in home waters in classes of vessel where weight is usually of vital importance.

A second set of tables was therefore prepared, which are known by actual tests to provide small deflections and negligible permanent sets, and which are not excessive in weight as judged by the standard for these classes of ship. It may be asked, what is the justification for any higher standard? but the obvious answer seems sufficient. In the event of accident to an ocean steamer, long voyages may have to be made with a hold in free communication with the sea, and the dynamic conditions may be so severe that an ample margin of strength is a precaution worth far more than the cost and weight involved.

The experiments have done more than justify practical conclusions; they have cleared up many matters which have hitherto been to some extent matters of opinion. For instance, there is a common feeling that the bellying of a bulkhead manifests itself not only vertically but also horizontally, and that the whole surface under pressure is curvilinear. The experiments, however, show that stiffeners close to the sides of the tanks and rigid points are constrained thereby, but an examination of the diagrams in Fig. 4 also shows clearly that the deflection on each stiffener is entirely influenced by local conditions of that stiffener. On "D" bulkhead the two channels next the side have been held back by the sides, but the next three show practically the same deflections, except that the change from 36 in. to 30 in. spacing has brought in the last channel a little, while it has in turn distinctly pulled in the adjacent bulb angle. The next four bulb angles are in a straight line, but the next two deflections drop in a curious fashion, which indicates peculiar local conditions other than mere shortening of span, probably the constraining effect of a stanchion and girder upon the points of the top brackets, while the remainder are also under this local influence and constraint from the sides. The other two diagrams, which show the deflections in the upper 'tween-decks and hold stiffeners of the B.T. bulkhead, clearly express the individuality of each stiffener without explanatory comment. It is unlikely that ordinary beam theories apply to deflections which exceed $\frac{1}{48}$ of the length, because permanent set is recorded in association with such amounts, and as $\frac{1}{100}$ with its corresponding set is evidently good enough for test heads on deep tank bulkheads, they cannot be a complete guide to structures where $\frac{1}{300}$ is a high standard for deflection.

The deflection diagrams of the B.T. and D. bulkheads show that straight pull upon the ends of the stiffeners begins to take effect at an early stage, becomes more marked as the deflections increase, and that the structure seems to find rest in a nearly perfect angle. The bulkhead diaphragm therefore tends to take the form of a dished plate, not of a flat cupola, and the forms of individual deflections are those which might be expected from a concentrated rather than a distributed load. Probably the key to the apparent contradiction between the necessity for taking into consideration both the I and the $\frac{I}{y}$ values in stiffeners, and the impossibility of estimating any but absurd stresses from beam formulæ, is to be found in these straight-line tendencies. The phenomena fit with the idea of an elastic beam tied firmly at the ends, adjusting itself to an increasing centre load, and obtaining relief from bending stresses by automatically shortening the virtual span.

The present experiments, Mr. Rowell's test of a bulkhead with 4½-lb. plating, and undesired experiments in practice, have shown that there is not much to fear from deflection as a phenomenon, and indicate that deflections can be pushed, without structural failure, to some point which is apparently limited chiefly by the adaptability of the ends of the stiffeners to meet changing conditions and by the tensile strength of the material. If the problem, therefore, were simply that of building a diaphragm which would hold water without leakage, it is probable that well-stiffened margins, double boundary angles, and the weight of stiffeners thrown into a flat plating would provide the best answer. The difficulty of securing a rigid rim on board ship is obvious, however, while it is evident that nothing could be attached to such a bulkhead, and that it would be useless as a cargo division.

Within the limits where riveting can hold the stiffeners on to the plating, the next best way to avoid leakage would be the use of light stiffeners without end attachments, as is shown by the overload carried by the upper 'tween-deck stiffeners in the B.T. bulkhead. All the

FIG. 5. "D" BULKHEAD.

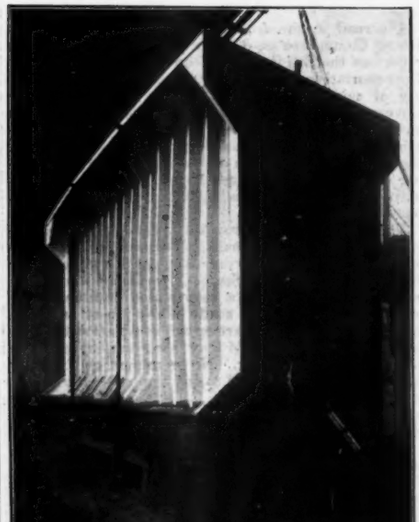


FIG. 6. "D" BULKHEAD.

experiments have had the effect of confirming a life-long antipathy to the use of heavy shallow sections, and the consequent necessity of attempting to prevent failure by massive end connections. The facts support the strong views expressed in word and practice, that the proper development of satisfactory stiffening on such an elastic structure as a ship is in the direction of reducing rivet stress by increasing depth of girder. They also support disbelief in the constant imminent risk said to be incurred by using deep sections, so called, which is popularly expressed by the "tripping" superstition. The remarkably good behaviour of such unstable sections as the flanged stiffeners having relatively high inertia value and small sectional area, in the B.T. bulkhead, would require a lot of explaining if these opinions are unsound.

The shape of the deflections suggests advantages in the shape of stiffeners recommended by Sir Edward Harland in his minority report in 1891, which were deep at mid-length, shallow at the ends, and secured by lugs; but such a form is rather outside practice in these days of rolled sections: it is to be hoped, by the way, that the number and depth of these sections will soon be largely increased. It is a distinct gain that the Committee have brought into prominence the efficiency as well as the practical advantages to be derived from deep stiffeners attached by lugs only.

Apart from the question of ultimate strength, it must be kept in mind that bulkheads are usually inaccessible when an accident occurs, and there is not much comfort in the knowledge that they will not give way under pressure, if unavoidable changes in shape cause broken joints, or carry away connections to runners and otherwise unimportant items. It does not take many odd rivets to cause leakage beyond the control of the ordinary bilge suctions. It is therefore essential that those responsible shall consider not only the required stiffness of each bulkhead, but the efficiency of everything which is attached to or which passes through it, in the light of the knowledge that the whole structure is going to move in all sorts of ways and to very distinct amounts, in the event of being called upon to keep out the ocean. A serious view of this responsibility is necessary if subdivision is to be that actual safeguard which it is intended to be.

NOTES FROM THE UNITED STATES.

PHILADELPHIA, April 5.

THE particular feature of the week is an advance of 5 dols. a ton on steel products, except rails. The crest of high prices, long looked for, is not in sight. The requirements for a great many new enterprises are held back. The steel-ingot output of the Steel Corporation has reached 69,000 tons a day. Advances in steel since January 1 amount to 13 dols. a ton as an average. All sorts of premium prices continue to be privately paid for preferential delivery. Since January 1 orders have been placed for 38,500 cars, against 7900 cars for the first quarter last year; locomotives, 930, against 300 same quarter last year. For 1916 most rail requirements have been covered, and over 1,000,000 tons ordered for early 1917 needs. The scarcity of steel is leading to the temporary use of underframes of wood for cars, to be later replaced by steel. It is estimated that last week's orders for steel exceeded 1,000,000 tons. Total steel orders since January 1 amount to nearly 10,000,000 tons, at an average cost of 50 dols. per ton, representing in value 500,000,000 dols. Among the past week's rail orders were—Southern Pacific, 45,000 tons; Missouri Pacific, 30,000 tons. Other systems are about to place large orders. Shipyard orders are crowding into 1917 deliveries. Sugar-planting interests in Cuba are preparing to build large steel storage warehouses which will call for much structural material. Large cotton warehouses are also under construction in the Southern States.

Russia has closed with the American Locomotive Company for 70 engines, the Missouri Pacific for 40, the Pennsylvania Company for 25, and the Great Northern Company for 25. These details indicate in a general way the condition of general demand, which by no means represent total requirements. The manufacture of munitions is at last under highest efficiency, headway and requirements placed at almost any figures are in clear sight. The Bethlehem Company has secured a large plant at Baltimore, and will largely expand its capacity. Powder plants in California are enlarging. Basic pig-iron is being contracted for in 10,000-ton lots. Enormous orders are awaiting acceptance for export for shell steel. In all several million tons are wanted up to July, 1917. Manufacturers refuse to tie themselves up for so long a time. Automobile-makers are scrambling for steel. A cold recital of facts does not convey any clear conception of steel market conditions.

METALLIC PERMANENT-WAY.—Our exports of metallic permanent-way—chairs and metallic sleepers—have been very considerably reduced by the war; in fact, they are almost for the present at an end, only 787 tons having been shipped in March, as compared with 6661 tons in March, 1915, and 10,843 tons in March, 1914. The aggregate shipments in the three months ended March 31, this year, were 2666 tons, as compared with 15,860 tons in the first quarter of 1915, and 25,586 tons in the first quarter of 1914.

SMALL PETROL FIRES.—The British Fire-Prevention Committee have recently carried out a series of tests, the results of which tend to prove that sawdust intimately mixed with bicarbonate of soda and applied in bulk has certain advantages over sand and similar materials as an extinguishing medium for comparatively small fires occasioned by the ignition of the vapour of petroleum spirit (petrol) and other inflammable liquids. When sawdust is applied to the surface of a liquid it will float for some time, thus excluding the oxygen of the air and smothering the fire. Ordinary sawdust, as obtained from saw-mills, is the most suitable for this purpose. It must be free from shavings and chips of wood, but it does not require to be either specially dried or to contain added moisture. The addition of bicarbonate of soda, although not essential, is advantageous. Under the action of the heat from the burning liquid, carbonic acid gas is given off from the bicarbonate of soda adhering to the floating sawdust, and accordingly close to the source of the fire. The gas given off under such circumstances slightly assists in extinguishing the fire. Bicarbonate of soda is readily obtainable at a very small cost. The Committee have found an effective proportion of bicarbonate of soda to sawdust to be 10 lb. to 1 bushel (or, say, 12 lb.) of sawdust. The Committee wish to emphasise the fact that so far their investigations have been limited to small quantities of inflammable liquids, not exceeding 2 gallons, and the areas over which they were spread did not exceed 6 ft. square. These conditions are met with in motor garages and hangars, for which, in the opinion of the Committee, the proposed mixture is applicable and economical. The Committee add that their tests showed that the application of this or any similar mixture in small quantities from tubes or canisters does not give satisfactory results.

INDUSTRIAL NOTES.

THE Director of the Department of Labour Statistics, dealing with the state of the labour market in March in the *Board of Trade Labour Gazette* says that the general high level of employment of recent months was fully maintained in March, and notwithstanding the increasing introduction of women into industry, the shortage of labour became still more acute.

The changes in rates of wages reported as taking effect in March affected nearly 459,000 workpeople, and resulted in a net increase of about 35,200*l.* per week. The principal changes were increases affecting over 377,000 coal-miners in Cumberland, Yorkshire, Lancashire, the Midlands, and North Wales; 18,500 semi-skilled and unskilled men in engineering and shipbuilding establishments on the Clyde; and 8000 men of similar grades in the engineering industry at Sheffield.

The number of disputes beginning in March was 44, and the total number of workpeople involved in all disputes in progress was 58,388, as compared with 12,831 in the previous month, and 33,903 in March, 1915. The estimated total aggregate duration of all disputes during the month was 327,300 working days, as compared with 102,600 in February, 1916, and 151,200 in March, 1915.

The average weekly number of vacancies notified to all Labour Exchanges for the four weeks ended March 10 was 35,337, as compared with 45,948 in the previous four weeks, and with 34,477 in the four weeks ended March 12, 1915. The average weekly number of vacancies filled for the same periods were 27,417, 28,902, and 24,797 respectively.

Mr. Arthur Henderson, President of the Board of Education and Chairman of the National Advisory Committee of War Output, met the Clyde shipwrights and boiler-makers last Saturday, the 15th inst. Last Sunday he discussed with the Clyde Labour Advisory Board the questions of dilution of labour and wages. In the course of a speech he made, Mr. Henderson said he had long been convinced that the war was a question of endurance, in which we and our Allies would be thoroughly tested both from the military standpoint and from financial and trade resources. That being so, we could not afford to waste or misapply the capacity of our highly-skilled workmen. During the early days of the war labour was transferred to Navy ships until the construction of merchant ships was brought to a standstill. We could no longer afford to neglect the building of merchant ships, and everything should be done to secure the rapid delivery of all merchant ships now under construction. It was absolutely necessary, therefore, that the employment of skilled men should be strictly limited to the work for which their skill was essential, and not directed to work which could be performed by men of lesser skill or by women. Moreover, all workers in shipyards and engineering establishments must have it brought home to them that their full time and whole-hearted service were indispensable to the winning of the war. In regard to wages, it was decided at the meeting to obtain information from the Clyde, the North-East Coast, Manchester, Birmingham and London, analyse the figures, and to place the matter before the Minister of Munitions and the President of the Board of Trade. Mr. Henderson also read a letter from the President of the Board of Trade stating that the principal reason for the scarcity of tonnage was the part that the British Mercantile Marine had been called on to play in the prosecution of the war by co-operating with the Fleet and by supplying transports and store-ships for the army; also that he was informed that one of the reasons for the delay in the delivery of merchant vessels had been the reluctance shown by workers in shipyards to engage upon merchant work, which had been regarded as of comparatively small importance in the prosecution of the war. With the express object of removing that apprehension a large number of merchant ships under construction had recently been declared war work. Mr. Henderson added that a minority of the workmen were still losing too much time.

At the boilermakers' meeting Mr. Henderson said that the trade-union movement, as a whole, had behaved nobly and had made most conspicuous sacrifices.

Up to Thursday evening, the 13th inst., says the *Textile Mercury*, there had not been any joint meeting of the employers and workpeople in connection with the operative cotton spinners' application for a 10 per cent. increase in rates of pay. Negotiations have been conducted with Sir George Askwith, but with what object no definite statement has been made. It is being assumed in some quarters that the meaning of the award given with regard to the wages dispute settled last July was that there should be no further applications for advances during the period of the war. This view does not appear to be accepted by the operatives' officials. The decision of Sir George Askwith will have an important bearing on the present application.

The report dated the 8th inst., issued by the Steam-Engine Makers' Society, states the membership to be now 20,300, distributed over 176 branches, with a capital of 180,000*l.* The unemployed number 11. This progressive society, which formerly requested its members to endeavour to reach a membership of 20,000, is now "asking for more," and has put the figure aimed at at 25,000 members.

The general secretary of the United Society of Boiler-Makers and Iron and Steel Shipbuilders writing in the society's report for the current month states the following:—

"... I feel quite sure that any man who advocates or takes part in a strike at this time does not realise the gravity of our position. I have talked to hundreds of trade unionists in France and Belgium, and in railway trains in this country, and I never yet spoke to one who favoured a stoppage on the manufacture of munitions of war. On the other hand, I have met many who failed to find ordinary English adequate to express their views on strikes of any kind. I can fancy some of the brave fellows I met at the Front reading the exaggerated newspaper accounts of the strikes at Parkhead and other works—brothers of ours at Verdun being pounded from a distance of some 8 or 10 miles by 15-in. German guns while they are patiently waiting for our own new big guns to send the Germans a suitable reply. I can imagine our men all along the line waiting for the completion of their batteries to begin a grand offensive in which our big guns will hew out a great broad path to victory. What must these men think of us?

"I have said this much on a question that is painful to me so that our members, whose loyalty is equal to that of any other body of men in the country, will not be foolish enough to forget their loyalty when faced with grievances and even injustice. We cannot strike work and win the war. ..."

We read in the *Iron Age* that the United States House Committee on Labour authorised a favourable report on the Bill introduced on January 11, 1916, by Representative Tavenner, of Illinois, prohibiting the use of scientific shop-management methods in any Government establishment. Immediately after the announcement of the action of the committee, however, a request was received from a representative of the National Association of Manufacturers for a hearing on the Bill. It is understood that this request will be complied with, and that the whole subject will be re-opened.

The Tavenner Bill provides "That it shall be unlawful for any officer, manager, superintendent, foreman, or other person having charge of the work of any employee of the United States Government to make or cause to be made with a stop watch or other time-measuring source a time study of any job of any such employee between the starting and completion thereof, or of the movements of any such employee while engaged upon such work. No premiums, or bonus, or cash services shall be paid to any employee in addition to his regular wages, except for suggestions resulting in improvement or economy in the operation of any Government plant."

The Tavenner Bill is strongly opposed by several national organisations of business men, including the Chamber of Commerce of the United States, which has authorised the appointment of a committee to oppose Federal legislation of this character.

PRECAUTIONS AGAINST ACCIDENTS ON THE PENNSYLVANIA RAILROAD.—In order to discover how well the train-operating rules and signals were being obeyed on the Pennsylvania Railroad system, considerably more than four million tests and observations, covering the work of both officials and employees, were carried out during last year. The results, which have just been compiled, show that only one error occurred in every 1110 trials, or that the working in this respect was 99.9 per cent. of absolute perfection. In four classes of tests, including the most important test of obedience to various "stop" signals, no failure on the part of any employee occurred throughout the year. An exceptionally good record was also made in the observance of rules especially intended for the protection of employees. In connection with the moving of trains 68,941 observations were made and 17 errors recorded, while with regard to the safety rules for track workmen the 342,991 tests made showed only 73 cases in which the rules were disregarded in any way. Failures strictly to observe the rules governing watchmen stationed at grade crossings occurred on only eight occasions, though 62,934 observations were made. The attention given to the matter of safety regulations is doubtless largely responsible for the fact that last year was the third in succession in which no passenger has been killed in a train accident on the system east of Pittsburg and Erie. Accidents to employees also continue to show a highly satisfactory diminution in numbers; those occurring last year were 11 per cent. less than in the previous year.

NOTES FROM SOUTH YORKSHIRE.

SHEFFIELD, Wednesday.

Hull Coal Traffic.—There was a further decline in the amount of traffic dealt with at Hull during the month of March. This is the outcome of the rigorous enforcing of the export restrictions. The total tonnage handled was 261,759, a reduction of 140,000 tons on the corresponding month of last year. For the first quarter of the year the total amount is 800,844 tons, or a falling off of 310,000 tons from 1915, and only half the quantity of two years ago. About 57,293 tons were exported to France in March, or one-half of the total forwarded to the same destination in March, 1915. During the quarter France has received 268,178 tons, half of the figure for last year, and considerably less than the total of 765,042 in the first quarter of 1914. The Denaby and Cadeby Main Collieries are about the only ones to maintain their positions.

South Yorkshire Coal Trade.—The activity in the market for manufacturing fuels is very pronounced. Works are eager to obtain large stocks to carry them over the holidays, but as the position has long been of a "hand-to-mouth" description, there are not sufficient reserves on hand to allow such a policy to be carried out. As a result the large establishments cannot contemplate the Eastertide with equanimity. Pits are expected to close down from Thursday evening until Wednesday, but by reason of the national importance of their industry, nearly all the large Sheffield establishments will only be on holiday for a very limited period, and in certain instances will work right through. The problem of the fuel supply, therefore, is of paramount importance, but it does not lend itself to an easy solution. Even where the stocks have been carefully husbanded there is very little surplus, and manufacturers will be obliged to extend the extravagant policy of still further adapting house-coal for industrial purposes. The "legitimate" demand for house-coal still declines, and collieries and merchants are thus better able to devote their attention to the serious state of the other departments. The inquiry for best steam is very brisk on the part of home consumers, whilst shipments for Allied countries are heavy. Gas fuels are going away freely to inland works on account of contracts, and there are also substantial orders for foreign ports. Cobbles, nuts, and smalls are a very difficult market, for the pressure of orders is beyond the ability of the merchants to deal with, and, as a consequence, prices are inflated, and likely to remain so for some time to come. Cokes are scarce, and easily maintain recent high rates. Quotations:—Best branch hand-picked, 20s. 6d. to 21s. 6d.; Barnsley best Silkstone, 18s. 6d. to 19s. 6d.; Derbyshire best brights, 17s. 6d. to 18s. 6d.; Derbyshire house, 16s. to 17s.; best large nuts, 15s. 6d. to 16s. 6d.; small nuts, 15s. to 16s.; Yorkshire hards, 16s. 6d. to 17s. 6d.; Derbyshire hards, 16s. to 17s.; best slacks, 12s. to 13s.; seconds, 11s. to 12s.; smalls, 8s. to 9s. per ton.

Iron and Steel.—The shortage of steel, which has been felt since the turn of the year, is now more severe, and anxiety is being expressed as to the continued decline in the supplies of Bessemer and open-hearth qualities. Already the lack of raw material has caused manufacturers to cease making certain classes of useful articles. The available home sources of steel manufacture have long been engaged on maximum output, and with the falling away in the quantities from neutral quarters, the smaller or less important consumers have been crushed out. The unofficial buyers have little chance when competing against the purchasers on behalf of the Government. The tungsten scarcity is retarding the output of high-speed steel, and makers of the alloy are held up by inadequate supplies of ore. Swedish steel output is becoming smaller, and imports are only at a low figure. Makers declare this to be due to the lack of the necessary fuel and ferro-manganese. The decline in the supplies has led to a further advance in prices; brands which in pre-war days were marked at 12*l.* are now 20*l.* dearer. The pig-iron market has a firm and settled tone; makers are strictly conforming to the Government regulations. Latest quotations are unchanged for West Coast hematites, whilst East Coast ordinary are 122s. 6d., and special grades from 135s. to 140s., plus cost of delivery. Buying is not very active. Forge and foundry-iron makers are not receiving the heavy orders they did in the latter days of March; but business is steady, with a tendency so become quieter with the approach of the holidays. Derbyshire makers are receiving 85s. 6d. for forge and 87s. 6d. for foundry iron. As to the list of maximum prices recently issued by the Ministry of Munitions, and already published in ENGINEERING, local makers severely criticise the figures. Apparently acid steel cannot be included, for 11*l.* per ton is the lowest figure it can be produced at. Dead soft billets are almost wholly supplied to the Government at 11*l.*, whilst bar-iron is 13*l.*, or 15s. less than the official maximum. Local makers, however, are easily obtaining premiums on their quotations. The falling-off in the orders and inquiries for the general trade continues to be considerable. On the other hand, enormous quantities of files, twist-drills, and different hand-tools are still on order, and will be sufficient to keep works running for twelve months. The Salford Corporation Tramway Department has placed a contract for steel tyres with a local firm and a twelve months order for iron and steel with another establishment. Overseas orders remain at a good figure, with axes, shovels, sickles, wire and steel in big demand.

THE LATE MR. ERASMUS DARWIN LEAVITT.—We regret to have to record the death, which occurred on the 11th ult., of Mr. Erasmus Darwin Leavitt, the eminent engineer, of Cambridge, Mass. We propose to give an obituary notice on the deceased in an early issue.

NOTES FROM CLEVELAND AND THE NORTHERN COUNTIES.

MIDDLESBROUGH, Wednesday.

The Cleveland Iron Trade.—For the time being business with the Continent is suspended. The prohibition of pig-iron exports was quite expected, and the wonder is that the action has not been taken earlier. Shipments to buyers abroad may, it is understood, still be made under licence, but exporters fully realise the great difficulty likely to be experienced in obtaining permits for delivery to any foreign countries but our Allies, and are making no effort to do business with customers on the Continent. What sales are passing are confined to transactions for home consumption at the fixed maximum rates. Since the publication of the prohibition order the attendances on 'Change have been very thin. No. 3 Cleveland pig-iron stands at 82s. 6d. for home consumption, and for export the quotation is nominal at 92s. Reliable quotations for other qualities of Cleveland pig-iron are not obtainable.

Hematite Pig Iron.—There is nothing new ascertainable concerning the East Coast hematite branch of the staple industry. A few odd sales of Nos. 1, 2, and 3 to home consumers occur from time to time at the fixed maximum of 122s. 6d., but there is practically no iron available for sale for supply earlier than three months ahead. The export quotation of mixed numbers remains at 140s., but the figure is nominal. Deliveries to France on contracts continue on a fairly good scale.

Stocks and Shipments of Pig-Iron.—Stocks of pig-iron are still dwindling and threaten to disappear altogether in the no distant future. Practically the only stock in existence is the 43,776 tons of Cleveland pig in the public warrant stores here, all of which, with the exception of 2332 tons of iron deliverable as standard, is No. 3 quality. So far this month 13,534 tons have been withdrawn from the warrant stores to meet current needs. Under the conditions prevailing, shipments of pig-iron from the port of Middlesbrough must be regarded as on a satisfactory scale. So far this month they amount to 29,741 tons, as compared with 26,720 tons to the same date last month, and 5195 tons for the corresponding part of April last year.

Foreign Ore.—One or two new features have entered the foreign ore trade. The situation is still peculiar. The intention of the Government to eliminate carrying competition has brought down freights. In the open market, however, the Bilbao-Middlesbrough freight is 22s., whereas consumers buying to manufacture iron for home use are able to arrange freights Bilbao-Middlesbrough through the Government at 17s. The f.o.b. price of Rubio of 50 per cent. quality has been raised 6d., in consequence, it is declared, of increased insurance, making the quotation at port of despatch 17s. 6d. Thus controlled consumers are able to purchase best Rubio at 34s. 6d. ex-ship Tees, but in the open market the quotation ex-ship Tees is 39s. 6d. Imports of foreign ore to the Tees to date this month amount to 119,839 tons.

Coke.—Business in coke for local use continues at 28s. at the ovens for medium blast-furnace kinds, and up to 30s. 6d. at the ovens for qualities low in phosphorus.

Manufactured Iron and Steel.—In the finished iron and steel industries manufacturers are as busily employed as ever on Government work. Quotations all round are strong. The tendency is to discontinue discounts that have been in vogue for years, and quote net. Following on steel shipbuilding material, joists, and other descriptions, this action has been taken with regard to iron bars, iron angles, and iron ship-plates, the two former of which have been advanced to maximum prices. Common iron bars are 13*l.* 15s.; best bars, 14*l.* 2s. 6d.; double best bars, 14*l.* 10s.; treble best bars, 14*l.* 17s. 6d.; packing-iron (parallel), 10*l.*; packing-iron (tapered), 11*l.* 10s.; iron ship-plates, 11*l.* 10s.; iron ship-angles, 13*l.* 15s.; steel ship-plates, 11*l.* 10s.; steel ship-angles, 11*l.* 2s. 6d.; steel joists, 11*l.* 2s. 6d.; and heavy sections of steel rails, 10*l.* 17s. 6d.—all net.

ASSOCIATION OF RAILWAY COMPANIES' SIGNAL SUPERINTENDENTS AND SIGNAL ENGINEERS (ENGLAND).—The fifty-second conference of the above Association will be held at the Railway Clearing House, London, on Thursday, May 11.

OPENINGS FOR BRITISH ARTICLES IN ITALIAN MARKETS.—The British Chamber of Commerce for Italy has recently issued two lists, Nos. 24 and 25, giving particulars of Italian firms who are seeking British connections. Information is also given in regard to the class of trade in each instance stated.

BUSINESS WITH HONGKONG.—The following statement is taken from *The London and China Telegraph*:—"Hongkong is affected by the order prohibiting Manchester and other places from continuing to supply goods to German firms in China. These goods, remarks the *Colonial Gazette*, are sold with a German trade-mark or 'chop,' and the natives have got used to them. The position is that the articles have to a very large extent been made in Great Britain, but have been handled by German firms—an arrangement which has been to the benefit of both parties. Unless the British firms can now step in and establish direct connections, the Germans will no doubt obtain some goods from neutral sources and continue to mark them with their brands, but it will not be easy to do so, and very high prices will have to be paid. The breaking up of the old combination will create a new situation, and it is to be hoped that British merchants in Hongkong will use it energetically in their own interests and those of British trade."

NOTES FROM THE SOUTH-WEST.

Cardiff.—There is every indication of the pressure for most descriptions of steam coal being maintained till after the Easter holidays. Tonnage has arrived in moderate quantities. Colliery outputs are reported to be slightly heavier, but colliery-owners have shown no disposition to relax quotations for either large coal or smalls, although dry coal has been in somewhat less active demand, and has been obtainable upon relatively easier terms. The best Admiralty large steam coal has been, to some extent, nominal; secondary qualities have made 48s. to 50s.; Monmouthshire black veins, 49s. to 50s.; Western Valleys, 48s. to 49s.; Eastern Valleys, 43s. to 45s.; best bunker smalls, 25s. to 27s.; and cargo smalls, 18s. to 21s. per ton. As regards bituminous coal, best households have made 23s. to 24s. at pit; No. 3 Rhondda large, 48s. to 50s.; No. 3 smalls, 26s. to 28s.; No. 2 Rhondda large, 36s. to 40s.; and No. 2 smalls, 18s. to 20s. per ton. The latest quotation for patent fuel has been 44s. to 46s. per ton. Special foundry coke for export has brought 57s. 6d. to 62s. 6d.; good foundry coke, 52s. to 57s. 6d.; and furnace coke, 42s. 6d. to 47s. 6d. per ton. In iron ore, Rubio has made 39s. to 40s. per ton, upon a basis of 50 per cent. of iron, and charges, including freight, insurance, &c.

Western Trade Matters.—On Monday the directors of the Bromhill Collieries, Limited, cleared off two years' arrears of dividend upon the six per cent. preference shares.—It is understood that the freedom of Cardiff will be formally presented to Lord Rhondda on the occasion of the unveiling at the City Hall next autumn of the series of historical statues which his Lordship has presented to the city.—Something of a coal famine is feared in Wales, and a quotation of 50s. per ton is in sight.—On the other hand, there has been some relaxation in freights, the rate from Cardiff to Genoa being 20s. per ton lower than it was a few weeks ago.—The steamer Bland Hall, built at Sunderland, in 1914, and carrying about 8250 tons dead weight, has been sold to British buyers for 180,000*l.*; she had been previously owned by Messrs. E. Nichall and Co., Cardiff.—It is proposed to divide some of the present 1*l.* shares in the Celtic Collieries, Limited, into two shares of 10s. each—viz., one 7 per cent. preference and one ordinary; the present capital of the company is 230,000*l.*, with 20,200*l.* debentures.—Quotations for tin plates are advancing almost from day to day; there is, however, only limited buying, as purchasers are only doing business from day to day.—The directors of the Port Talbot Graving Dock and Shipbuilding Company, Limited, have declared an interim dividend at the rate of 8 per cent. per annum.—The directors of the Sutherland Steamship Company recommend a final dividend of 4s. per share for the past financial year; the dividend is to be paid tax free, and that is, of course, a consideration.—The directors of the South Wales Electrical Power-Distribution Company, Limited, state that the business of the company showed a material increase in 1915, 28,967,656 units having been sold, as compared with 26,510,198 units in 1914. After payment of working expenses, interest on prior lien debenture stock, and allowance for depreciation, there was a surplus of 6756*l.* for 1914, as compared with a corresponding surplus of 5347*l.* for 1914. Last year's surplus was applied to the payment of further debenture stock interest, 1756*l.* being also added to a suspense account.

AMERICAN POWER PLANT.—The West Penn Power Company has now a 60,000-kw. station at Connellsville, Pennsylvania. The company is building a 150,000-kw. power-station at Willsburg, West Virginia, and proposes also to develop a 100,000-kw. plant on the Allegheny at Freeport, Pennsylvania. The West Penn Company now has 40,000-horse-power turbines being built by the General Electric Company, while the next unit purchased may be one of 50,000 horse-power.

SILICON-BRONZE WIRES OF 1000 FT. SPAN.—In connection with the electric-power distribution in the Province of Pommerania, Prussia, a strait of the Baltic has been crossed by stranded conductors of a length of 1000 ft. The River Oder flows (some miles below Stettin) into the Stettin Haft, which is separated from the Baltic by the islands of Usedom and Wollin, but communicates with the Baltic by three, mostly shallow channels known as Peene, Swine, Dievenow. It is the easternmost of these channels, the Dievenow, which has been crossed. On each bank an iron mast, 50 m. (165 ft.) high, has been erected. The ground on both banks is marshy, and ferro-concrete foundations had to be sunk to a depth of 6 m. into the moor, in which they rest on piles. Four concrete piers have been fixed at the corners of a square of 6 m. wide; on and in these piers rests the concrete basis proper of the mast. It was originally intended to build each mast in three sections, and to join the sections up while the mast was lying on the ground, before erection. There was, however, an accident, states J. C. Bohnenberger, in the *Elektrotechnische Zeitschrift* of December 9 last. The bottom section, therefore, was fixed first, and the two other sections were then raised on it and fitted in position. Each mast weighs 67.5 tons. The masts support three stranded conductors of 25 mm. sq.; the width of the channel is 304.5 m., and the wires sag by 16.5 m., leaving a clear height of 35 m. (117 ft.) above mean water-level. A special hydro-electric power-station was to be built in the district. For the present the line has been joined to the central power-stations at Stralsund, Stettin, Swinemünde and Belgard, the last of which is over 70 miles from the Dievenow. The feeders carry three-phase current at 40,000 volts. There are many large farms in Pommerania on which electric power is largely utilised.

MAXIMUM PRICES OF COKE AND BAR IRON AND STEEL.

IN continuation of the list of maximum prices given on page 351 *ante*, the Ministry of Munitions forwards the following:—

COKE.

	Per Ton Net F.O.T. Makers' Ovens. £ s. d.
Durham:	
Blast-furnace coke	1 8 0
Special blast-furnace coke, guaranteed under 0.008 of phosphorus	1 10 6
Foundry	1 10 6
South Yorkshire, West Yorkshire, North Staffordshire, North Derbyshire, South Wales	1 4 0
Blast-furnace coke	1 10 0

MAXIMUM PRICES OF STEEL.

	Per Ton F.O.T. Makers' Works. £ s. d.
Angles, ordinary sizes	11 2 6
Joists	11 2 6
Ship-plates	11 10 0
Boiler-plates	12 10 0
Rails (railway)	10 17 6
Sheet and tin-plate bars	10 7 6
Billets, ordinary mild steel	10 7 6
,, special	11 0 0

All plus usual standard extras.

BAR IRON.

	Per Ton Net F.O.T. Makers' Works. £ s. d.
South Staffs:	
Standard quality, ordinary sizes and merchants lengths	13 15 0
Marked bars (less 2½ per cent.)	15 0 0
South Yorkshire:	
Standard quality, ordinary sizes and merchants lengths	13 15 0
North of England:	
Standard quality, ordinary sizes and merchants lengths	13 15 0
Lancashire:	
Standard quality, ordinary sizes and merchants lengths	13 15 0
Scotch Bar Iron	
Standard quality, ordinary sizes and merchants lengths	13 15 0

All subject to the usual extras for special sizes and qualities.

These prices are not intended to apply to sections rolled by manufacturers who do not make their own steel or puddled bars, but have to purchase blooms, billets, or puddled bars from other sources.

HIGH-SPEED TOOL-STEEL.

The maximum prices for high-speed tool-steel have been fixed as follows:—Finished bars, 14 per cent. tungsten, 2s. 10d. per lb. basis; ditto, 18 per cent. tungsten, 3s. 10d. per lb. basis; usual trade extras for special sizes, &c. These prices are net delivered buyers' works.

The fixed prices for scrap, which must be returned to steel-makers' works, are as follows:—Millings and turnings, 6d. per lb. net, delivered steel-makers' works; bar ends, 6d. per lb. net, delivered steel-makers' works.

It should be added that these maximum prices have been fixed until June 30, 1916, and thereafter until further notice, and, further, that the makers may sell for delivery after June 30, 1916, on the understanding that the fixed maximum prices ruling on the first day of any month during the period of the contract will apply to all deliveries made during that month. These maximum prices are based upon the abnormal costs and conditions now prevailing, and must not be assumed to be indicative of any difference in relative values which may have obtained in the several districts before the war, and may obtain again after the war. This intimation must not be taken to authorise any sale or purchase or other dealing prohibited under the Defence of the Realm Regulations.

THE MOTOR-CAR RED-BOOK, 1916.—This book for the present year—the sixth annual issue—is compiled by Messrs. W. C. Bersey and W. V. Foucart, and is published by the Technical Publishing Company, Limited, 1, Gough-square, Fleet-street, E.C., at the price of 5s. 5d. net, post free. It contains an alphabetical list of motor-cars and cycle-cars manufactured from 1910 to 1916, with their list prices for each year. Similar information is given for motor-cycles and commercial motor vehicles. The marine motors are also dealt with in the same way, the prices for 1916 being quoted. The book contains, further, an alphabetical list of the aircraft and engines manufactured in 1916, and a very detailed trade index under several headings.

OUR COAL ABROAD.—The exports of coal from the United Kingdom in the three months ended March 31, this year, were 9,290,828 tons, as compared with 11,219,726 tons in the first three months of 1915 and 17,430,369 tons in the first three months of 1914. These totals were increased by the addition of coke and patent fuel to 9,775,276 tons, 11,698,248 tons, and 18,234,299 tons respectively. Bunker coal was also shipped for the use of steamers engaged in foreign trade in the first three months of this year to the extent of 3,273,225 tons, as compared with 3,978,631 tons and 5,035,448 tons respectively. In one form or another coal has accordingly been leaving our shores at the rate of 52,194,004 tons per annum, as compared with 62,707,516 tons in 1915 and 93,078,985 tons in 1914. The exports of coal, coke, and patent fuel in March were 3,281,793 tons, as compared with 4,143,756 tons in March, 1915, and 6,170,720 tons in March, 1914.

A COLLISION INVESTIGATION: THE S.S. "STORSTAD" AFTER COLLISION WITH THE "EMPRESS OF IRELAND."

(*For Description, see Page 387.*)

FIG. 4.

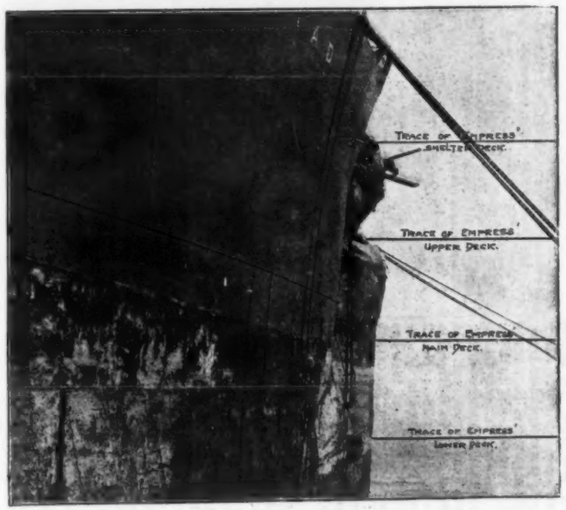


FIG. 5.

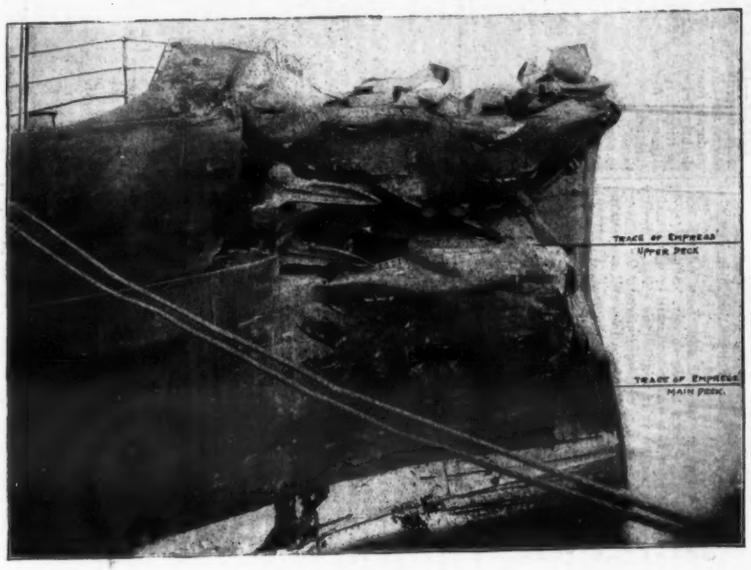


FIG. 6.

GRINDING MACHINES; EXAMPLES OF STEADIES OR BACK-RESTS.

(For Description, see Page 365.)

Fig.337.

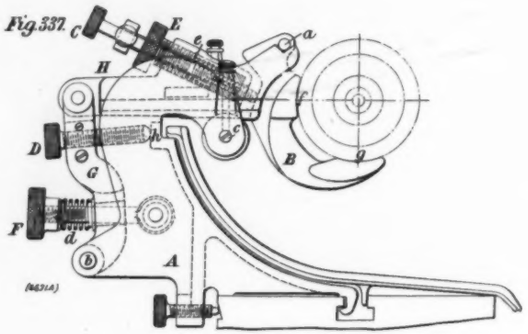


Fig.338.

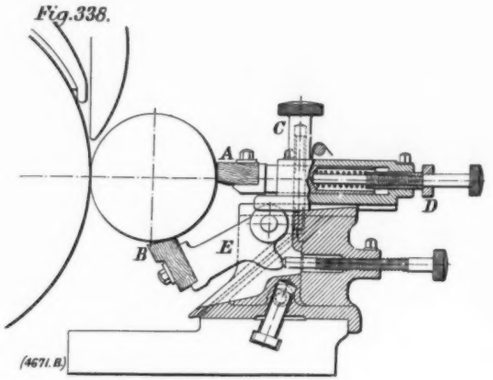
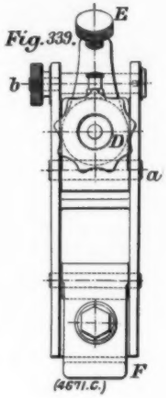


Fig.339.



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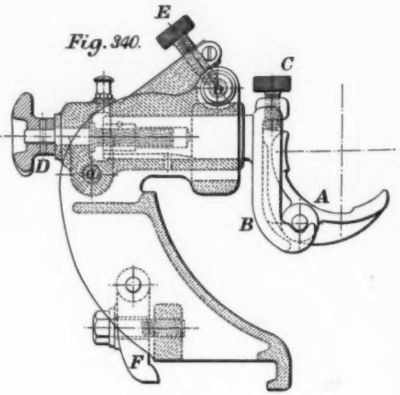

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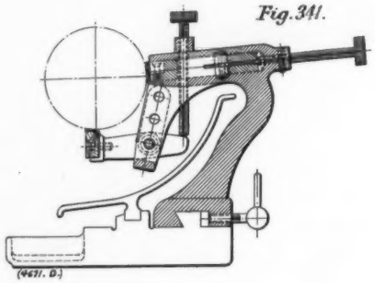

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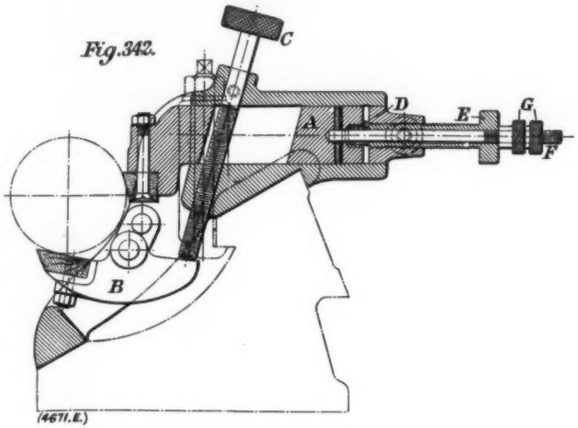

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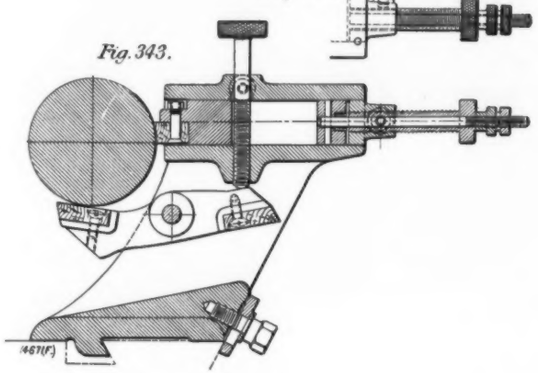


Fig.344.

Fig.345.

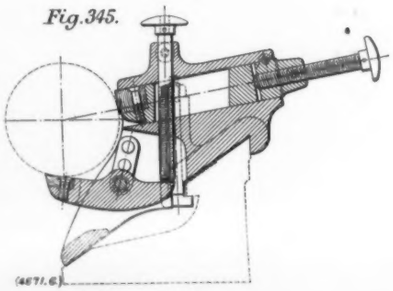
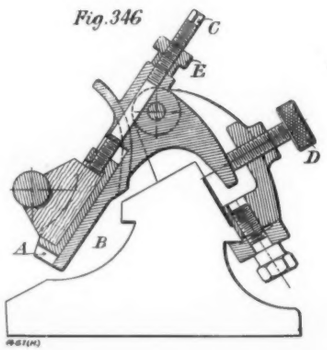


Fig.346



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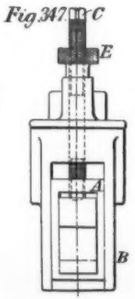

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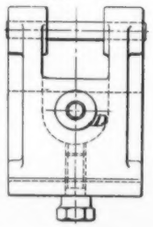

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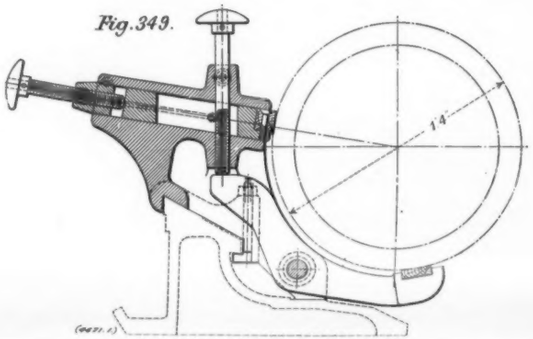
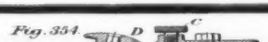


Fig.350.

Fig.354



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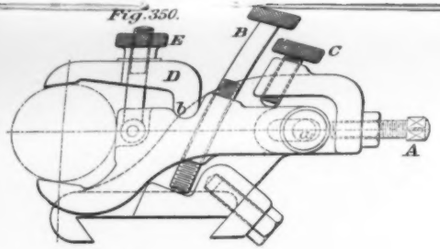

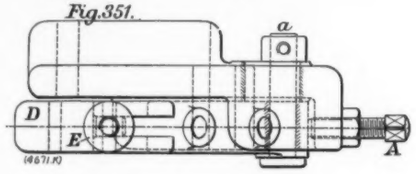

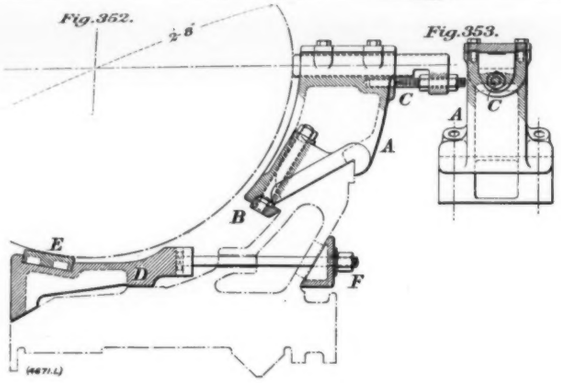

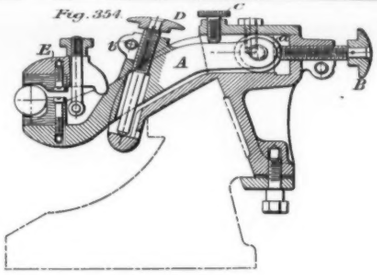

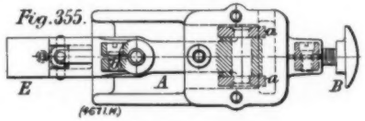

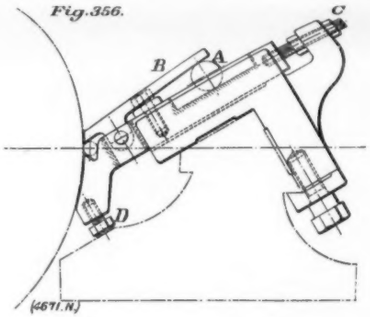

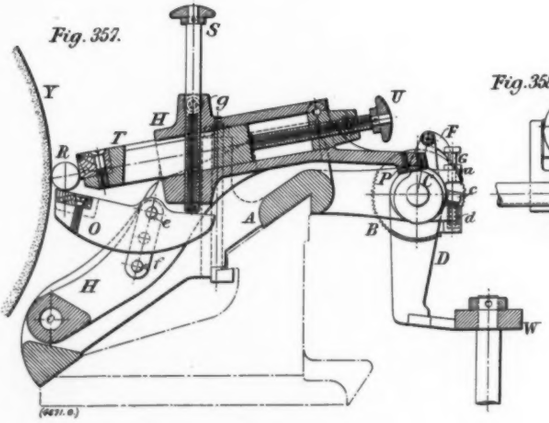

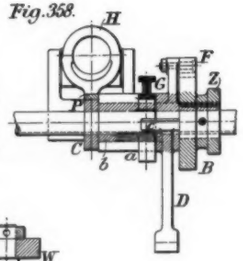

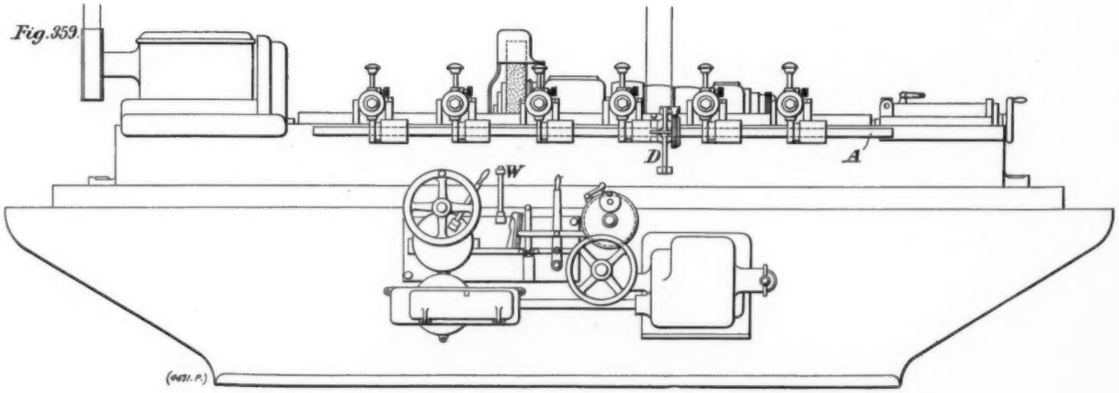

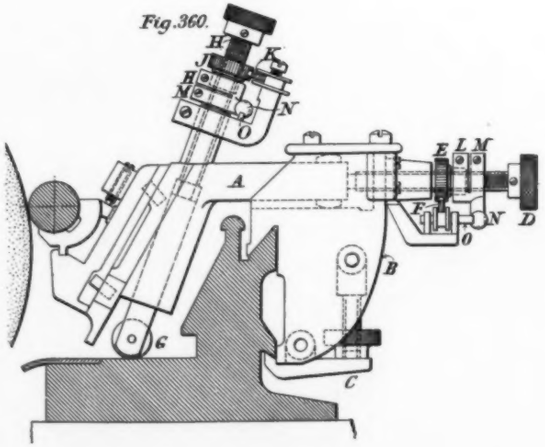

FIG. 337. A STEADY BY THE BROWN AND SHARPE MANUFACTURING COMPANY, PROVIDENCE, R.I., U.S.A.

FIG. 338. A STEADY BY THE LANDIS TOOL COMPANY, WAYNESBORO, PA., U.S.A.

FIGS. 339 AND 340. A STEADY BY THE NARRAGANSETT MACHINE COMPANY, PROVIDENCE, R.I., U.S.A.

FIG. 341. A STEADY BY THE QUEEN CITY MACHINE-TOOL COMPANY, CINCINNATI, OHIO, U.S.A.

FIGS. 342 TO 359. VARIOUS STEADIES BY THE CHURCHILL MACHINE-TOOL COMPANY, LIMITED, MANCHESTER.

FIG. 360. A STEADY BY THE NORTON GRINDING COMPANY, WORCESTER, MASS., U.S.A.

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The charge for advertisements is three shillings for the first four lines or under, and eightpence for each additional line. The line averages seven words. Payment must accompany all orders for single advertisements, otherwise their insertion cannot be guaranteed. Terms for displayed advertisements on the wrapper and on the inside pages may be obtained on application. The pages are 12 in. deep and 9 in. wide, divisible into four columns of 2¼ in. in width. Serial advertisements will be inserted with all practicable regularity, but absolute regularity cannot be guaranteed.

Advertisements intended for insertion in the current week's issue must be delivered not later than 5 p.m. on Thursday. In consequence of the necessity for going to press early with a portion of the edition, alterations for standing advertisements should be received not later than 1 p.m. on Tuesday in each week.

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Offices for Publication and Advertisements, 35 and 36, Bedford-street, Strand, London, W.C.

We desire to call the attention of our readers to the fact that the above is our SOLE ADDRESS, and that no connection exists between this Journal and any other publications bearing somewhat similar titles.

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TELEPHONE NUMBERS—3663 and 8596 GERRARD.

S.S. "PERSIA" AND S.S. "MALOJA."

The Publisher desires to notify subscribers to "ENGINEERING" in the East who did not receive their copies of "ENGINEERING" of the issues of December 17, 1915, and February 25, 1916, that they may have gone down with the mails in the S.S. "Persia" and S.S. "Maloja." A few copies are still in stock of each of these issues, and may be secured at the ordinary rates, plus postage.

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With a Two-Page Plate of GRINDING MACHINES: EXAMPLES OF STEADIES OR BACK-RESTS.

NOTICE OF MEETING.

THE ROYAL SOCIETY OF ARTS.—Thursday afternoon, April 27. A paper on "Scientific Agriculture in India," by Mr. James MacKenna, M.A., I.C.S., will be read by Sir Steyning W. Edgerley, K.C.S.I., K.C.V.O., C.I.E. Sir Robert W. Carlyle, K.C.S.I., C.I.E., Member of the Council of the Governor-General of India, 1910-15, will preside. The chair will be taken at 4.30 p.m.

NOTICE TO NON-SUBSCRIBERS.

In view of the restrictions now imposed by the Government on the importation of paper, and of the consequent shortage of supplies, readers who wish to be sure of obtaining "ENGINEERING" each week should place an order for the Journal with a newsagent or bookstall clerk. Owing to the scarcity of paper it will be impossible in future fully to provide for a chance demand for this Journal.

ENGINEERING.

FRIDAY, APRIL 21, 1916.

SCIENCE AND INDUSTRY.

WHILST we most thoroughly believe that the liquidation of the enormous war debt now being piled up can only be effected, without grave discomfort to the public at large, by a much closer application of science to industry, there is perhaps some danger that the public may be led to expect too easy and too immediate returns. Speaking recently to the Aberdeen Chamber of Commerce, Professor F. Soddy, F.R.S., is reported to have claimed that a chemist "might be able to put on half a sheet of notepaper that which would keep a whole class in the community in prosperity for a generation." At the best such a statement is only true in a very limited sense, and, we fear, may prove dangerously misleading. Between what Mr. James Swinburne has called "raw" science and industrial science there is a very great gulf fixed, which it is the province of the engineer or industrial chemist to bridge. That the heavy electrical industries of the present day are based on the discoveries of Michael Faraday is universally recognised, but the commercial and industrial value of these as they came from Faraday was insignificant. A prodigious effort of thought, years of toil, and great courage on the part of financiers were needed to make remunerative the vast territory through which Faraday drove his pioneering path. The same statement holds as to wireless telegraphy, which originated in the laboratory experiments of Hertz; but without the intent intelligence of Marconi and the faith and daring of those who financed him during many lean years, electric waves would still probably be merely a curiosity of the laboratory.

The assumption that raw science as it comes from the laboratory of the pioneer is of immediate commercial value appears also to be made in an article recently contributed to *The Times* by Professor W. C. McC. Lewis, head of the Department of Physical Chemistry at Liverpool University. Professor Lewis observes that "the great stumbling-block in the way of greater reciprocity between science and industry is simply the lack of recognition of the fact that the step between a scientific principle and an industrial operation is, as a rule, an immediate one." We hardly think that this contention is supported by practical experience in general. Indeed, the instance he takes to show this presumed close connection between pure science and its technical application is a singularly unhappy one. He observes, very rightly, that the prevention of tube corrosion in surface condensers is of the utmost importance, and quotes an official report to the effect that the annual loss from this cause in the United States Navy alone amounts to two million dollars. It was, of course, for reasons of this kind that the Institute of Metals arranged for the investigation now in progress at Liverpool University, and we are fully of the opinion that the investigation should be continued and liberally supported. Nevertheless, although the research has now extended over several years, hardly anything of immediate practical value has as yet accrued. Indeed, the few tentative recommendations embodied in the last report of this Committee showed that those responsible for the conduct of the research had paid insufficient attention to the engineering aspects of the problem. Thus the suggestion was made that the rate of corrosion should be reduced by sending the circulating water through the tubes all in parallel instead of, as usual, having two or more "nests" of tubes in series with each other. Such a proposal would either involve a material increase in the power expended in pumping the circulating water, or, alternatively, it would, owing to the reduction in the water speed, imply an enormous decrease in the efficiency of the cooling surface. This, in its turn, would result in a bad vacuum, and consequent great increase in the fuel consumption. The only practicable plan of preventing tube corrosion dealt with at the recent meeting of the Institute of Metals appears to owe little or nothing to the researches made at Liverpool. Nevertheless, the work of the Committee should undoubtedly be continued, but the connection between the observations there made and practical work is not likely to be very direct or immediate, as the investigators almost of necessity are lacking in that practical experience which is generally required to adapt laboratory results to industrial ends.

The true relationship between the science of the schools and that of the workshop is, we think, far more accurately set forth by Dr. L. H. Baekeland, in an address to the New York section of the Society of Chemical Industry, on the award to him of the Perkin Medal. Laboratory science is, in fact, seldom comprehensive enough to be applicable to practical ends without careful collation and correction. A pioneer cannot, in the nature of things, be expected to make more than a general reconnaissance of the field covered by his investigations. The exact features of the territory he opens must accordingly be established by a much more elaborate survey than he is in a position to make, and this operation almost invariably implies much thought, much labour, and a very heavy cash expenditure.

Dr. Baekeland observes that when engaged in teaching chemistry he believed everything to be as simple as the text-books indicated. This view lasted until he tried to make silver bromide for the commercial preparation of photographic emulsions. Stas, it was true, had recognised three or four different varieties of this salt, but Dr. Baekeland says that his own experience forced him to the conclusion that there were perhaps a hundred varieties, of which one only would ensure him success as a manufacturer. Again, he relates that it took four years and an expenditure of 300,000 dols. to make a commercial success of the Townsend diaphragm cell for the electrolytic production of caustic soda. Indeed, Dr. Baekeland delivered an emphatic warning against such views as those we are criticising. The assumption that the step between a scientific principle and its industrial application is immediate has led again and again to the erection of full-sized plants, in the hope of securing an immediate return, before all the doubtful details have been eliminated—a process which is generally only practicable by experimenting under approximately commercial conditions, even if it be on only a somewhat moderate scale. The consequent setback to an extension of the application of science to industry, is, perhaps, only one degree less serious than when some promising idea gets into the hands of a Stock Exchange speculator wholly uninterested in attaining industrial success, and anxious merely to unload at a profit his risks on to a confiding public.

LOW-TEMPERATURE CARBONISATION OF COAL.

THE theoretical advantages of low-temperature carbonisation of coal, which have formed the subject of numerous lectures and papers during recent years, have attained to high practical importance since the war began. The demands of the Government for the various raw materials of high explosives have obliged the gas companies to discontinue the manufacture of water-gas and to confine themselves to the use of coal alone, with the result that the output of coke has increased, and it has become a matter of difficulty to find customers for it. Gas-coke falls between two stools; it is not hard enough for metallurgical purposes, and it is somewhat too hard for domestic needs. It has, of course, a fairly defined field of usefulness, but this is limited, and it is not easy to widen it except by a greater reduction of price than the companies care to give. What the Government needs is tar, and not either coke or gas; and high-temperature carbonisation, such as is conducted in a gas works, is not favourable to a great yield of tar. Low-temperature carbonisation, on the other hand, yields a great amount of tar rich in many of the bodies which are in special demand just now, while the coke, when

the process is successfully conducted, is admirably fitted for domestic uses, as it lights readily and burns with a flame.

According to Professor Bone, low-temperature distillation (say at 400 deg. to 500 deg. Cent.) has the effect of decomposing the smoke-producing resinous constituent of coal. The tars obtained are richer in light oils than ordinary gas works tars, and contain paraffins, naphthalenes, as well as benzenes and phenols. The gas obtained is smaller in volume, but richer in its content of methane and paraffins. Mr. Harold Moore, M.Sc., speaking before the Manchester Association of Engineers last February on fuel-oils from coal, said that horizontal gas-retorts yielded 5½ per cent. by weight of tar from the fuel used, coke-ovens yielded 4 to 5 per cent. of tar, while the low-temperature processes yielded 10 to 20 per cent. of tar. The following is an estimate (not by Professor Bone) of the residual products from the tar resulting from the low-temperature combustion of 200 tons of coal :—

Sulphate of ammonia	2.68 tons
	gals.
Benzol, 90s.	62½
Toluol, 90s.	82
Xylol, 90s.	21
Solvent naphtha	63
Heavy naphtha	163
Carbolic acid...	48
Cresylic acid	507
Creosote	460
Lubricating oil	180
Diesel-engine oil	190
Total	1776½
Pitch	9 tons

In addition the rich gas produced can be washed for benzol, toluol, and xylol, the quantities obtained being put at 600 gallons, 100 gallons, and 20 gallons respectively. The importance of benzol as a motor fuel is very great, for not only does it serve our present enormous needs, but it also aids in maintaining the balance of trade, which is heavily against us.

It must not be forgotten the low-temperature carbonisation presents many difficulties, as numerous persons have found to their cost, and in addition to the technical difficulties of the process itself there is the question of educating the public in the use of an unaccustomed fuel, and in gaining the zealous co-operation of tar-distillers and others, who have to adapt themselves to new products. There is reason to believe, however, that these difficulties are fast disappearing, for the Treasury is giving financial assistance to the building of a large carbonisation works at Barnsley, and we all know with what aversion they regard all speculative expenditure. A 50-ton unit is nearly completed at the works of the Old Silkstone Collieries, Limited, Barnsley. A tar-distilling and benzol-recovery plant is being erected, and arrangements are being made with the Yorkshire Electric Power Company to take the bulk of the washed gas for fuel purposes. The coke is, of course, to be sold.

The experiment, it will be seen, is to be conducted on a really commercial scale and under the most favourable conditions, for there is, during the war, a most ample demand for all of the products, except the lighting gas, and, as explained, a market has been found for that. The colliery has, it is stated, undertaken to supply up to 200 tons of suitable slack per day.

There is, we understand, a project on foot for another works, representing a combined manufacture from which there will be little or no residual coke. The scheme is to use low-temperature carbonisation as the first stage in a manufacture of which the final outcome will be tar products, electric energy, and artificial nitrogenous fertilisers. It is intended that the station shall supply current for lighting, as well as for the furnaces, and so it will have a load factor of 60 per cent. or more. The fertiliser process is the one that starts with the production of calcium carbide, of which one of the constituents is coal in some form, and ends in cyanamide, which is capable of many transformations. The gas will be used for power generation, and the coke in the carbide furnaces.

RADIATIONS FROM ATOMS AND ELECTRONS.

ON Saturday afternoon last, Sir J. J. Thomson, O.M., P.R.S., delivered, at the Royal Institution, the concluding lecture of his extraordinarily interesting course on the above subject. On this occasion he said that at the end of his last lecture he had referred to Stark's discovery of an effect produced on the lines given out by a body when this body was exposed to a strong electric field. A number of cases were represented in Figs. 1, 2, and 3, from which it would be seen that the effect produced on the lines was by no means uniform even when these lines all belonged to the same spectral series. Thus the red line of hydrogen was, it would be seen, broken up into three components, the β line into four, whilst the resolution of the γ and δ lines was of a still more complex character. All these lines belonged to the same Balmer series, and yet the effect of the electric field on them was, it would be seen, very different. In the case of helium, again, there were similar anomalies. The D_3 line, for example, was not affected at all, but the others were, and in increasing degrees of complexity the shorter the wave-length, the line with wave-length 3820 being, it would be seen, broken up into two sets of four components each. In the case of lithium, again, it would be seen that whilst one line was quite unaffected, another was broken up into two sets of three components, and still another into two sets each of four components. Thus the effect of an electric field was not only complex, but varied in the most striking

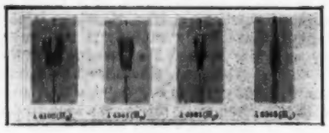


FIG. 1. STARK EFFECT ON HYDROGEN.

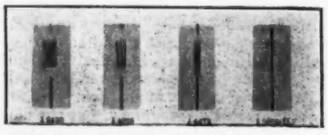


FIG. 2. STARK EFFECT ON HELIUM.

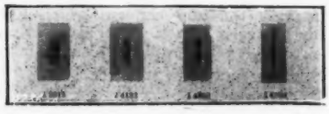


FIG. 3. STARK EFFECT ON LITHIUM.

way even when the lines concerned belonged to the same series. The strength of the field in these experiments was 28,500 volts per cm.

The effect of an electric field was, Sir Joseph continued, responsible for the great broadening of the lines observed in certain conditions. Thus when the spectrum of hydrogen was produced by the discharge through a vacuum tube, a great number of ions were liberated, and the electric field in the immediate neighbourhood of one of these ions was very large. Hence a luminous atom, if close to one of these ions, would be emitting its light in a strong field, and its lines would therefore be split up in a manner analogous to that represented in Fig. 1. The latter, however, showed the effect of a uniform field, but the field in the discharge-tube was by no means constant. Hence the constituents sent out would be spaced at different distances from the "rest" positions of the lines, and we got accordingly not detached components, but a spreading out of the line into a kind of ribbon. We should thus expect when the lines were emitted amidst charged atoms that they would broaden out and become more like bands, because the luminous centres were then exposed to strong electric fields of all kinds of intensities, giving rise accordingly to components at all distances from the normal position of the line.

The explanation of this effect of an electric field was not yet quite clear. He might, however, call attention to a possible way of looking at the matter closely analogous to that he had adopted in describing the Zeeman effect. He had, in a previous lecture, shown that we could picture this effect if there were, in the atom, directions in which the magnetic field was very strong and if the spectral lines were due to electrons spinning round the lines of magnetic force. Anything that varied the magnetic field would alter the speed of the spin, and in consequence of this, the position of the line in the spectrum. It was natural to look to a movement of electrons as responsible for the magnetic field. In fact, if an electron described a circle it gave rise to a magnetic field very similar to that which would be produced by a current of electricity flowing round the same path. Hence a revolving electron was the equivalent of a magnet, the strength of the field produced being proportional to the moment of momentum of the electron about the centre of its motion. If this moment of momentum were altered, the magnetic force would also be altered. If, therefore, we had in the atom the electrical analogue of a magnet, the position of the lines in the spectrum would be changed by the application of an external electric field. Suppose within the atom there was accordingly a negative charge lying close to a positive charge, the two forming a di-pole. Lines of force forming closed circuits would go out from this di-pole, as indicated in Fig. 4, and at a certain point the direction of this force would be at right angles to the axis of the di-pole, and an electron placed at A would be attracted in the direction of the force. If it were revolving steadily round the di-pole axis, it would produce a magnetic field having a moment proportional to va, v being the velocity of the electron. Hence, if another electron fell into the atom and spun round the axis of the field produced in the way just explained, this incomer would have a certain definite rate of revolution. If now an external electric force were applied, the electron, the steady motion of which produced the magnetic field, would have to find a new position of equilibrium, where the external force would just balance the force of the di-pole. The orbit described by it would therefore be shifted, and the moment of the magnet equivalent to it would be changed. Hence, if an electron now fell in as before, giving rise to a spectral line, this line would be shifted from its normal position.

In another way of looking at the matter, the shift of the spectral line was attributed directly to the change in the orbit of the electron responsible for the magnetic field. It was, however, difficult to believe that the spectral lines could be due to electrons in steady motion in a circle. If such particles were emitting radiation, they must be losing energy, and their paths could not therefore be stationary. The electron would be bound to fall in, the radiation would come to an end, and there would, moreover, be no guarantee that the time of vibration of the light emitted during the process would remain the same throughout. If there were appreciable radiation from an electron traversing a steady orbit, it would accordingly be difficult to reconcile this emission of energy with the steadiness of the position of the spectral lines, which must, it would seem, be in such case drawn out into bands. If, however, there were no radiation, there would be no light. It would be seen from these considerations that there were formidable difficulties in attributing the spectrum to radiation from electrons in steady motion, and for concluding that the lines must be produced in conditions of rapid change, as when an electron entering from the exterior spun round a line of magnetic force.

One point of great importance was the constitution of the energy of light. Newton regarded light as consisting of a number of small particles moving at great speed. On his theory, therefore, light was molecular in structure, its molecules being his corpuscles, each of which represented a perfectly definite unit. On the undulatory theory, on the other hand, the energy of light (implicitly at least) was regarded as a perfectly continuous quantity. This theory had had an enormous success in explaining optical phenomena, in which connection it had long been the only one to be considered. From a historical standpoint, however, it was interesting to note that if our knowledge of the electrical effects of light had been developed in Newton's time, the case for his view would have appeared so overwhelming that the speaker did not believe that the undulatory theory would have ever got through the early stages of its development. These effects of light on electricity could be accounted for very simply on Newton's view, but were exceedingly difficult to explain on the ordinary conception of the undulatory theory. What was required was some way of combining the two so as to get the steadiness of the train needed in optical

phenomena, with the individual units of energy required to account for the electrical effects. He could not, the lecturer proceeded, show at a public lecture, in quantitative fashion, the experiments which inclined physicists to believe that light had some kind of molecular structure. Evidence of the most straightforward kind was, however, afforded by the action of light on a plate of metal. If, for example, ultra-violet light were allowed to fall on such a plate, it made the metal shoot out negatively-charged particles, and with some considerable velocity. This velocity could be measured by finding to what positive potential the plate must be charged in order to prevent the escape of the particles. Investigations thus made showed that the velocity with which the particles shot out, did not depend in the least on the intensity of the light, but only on its quality. On the undulatory theory, it would be natural, however, to expect that the more the light energy falling on the plate, the greater should be the speed of the particles shot out. Actual experiment, on the other hand, showed that this speed was the same whether the source of light were close up to the plate or the length of the room away. So long as there was no change in the quality of the light used, the energy in each little particle shot out was simply proportional to the number of vibrations made per second by the exciting light. This energy (E) was, in fact, given by Planck's relation—viz. :—

$$E = h n,$$

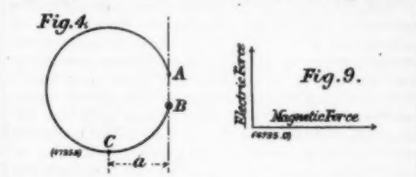
where h was an absolute constant and n the number of vibrations made per second by the light. This was a very remarkable result. The energy of the particles did not depend upon the amount of light energy falling on each unit surface of the plate, but only on the frequency of this light, and with this frequency it was connected in the above very simple way.

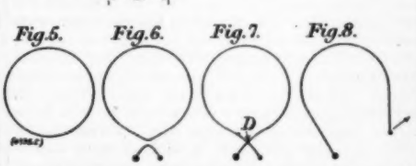
The kind of effect discussed above was shown by the lecturer by an experiment in which a metal plate was connected up to a gold-leaf electrometer, and exposed to the action of ultra-violet light. With the plate negatively charged the electroscope was rapidly discharged, whilst when the plate was positively electrified there was no loss of charge ; the negative particles which would otherwise have been liberated by the action of the light being retained by the attraction of the positive charge. By measuring accurately what positive charge just sufficed to stop the emission the velocity natural to the particles could, Professor Thomson said, be determined. The results showed that this velocity depended solely on the wave-length of the light, being, when due corrections were made, independent even of the nature of the substance acted on. This result could be easily explained on Newton's view, according to which, if more light corpuscles struck the plate, more particles would be liberated ; but the speed with which they came out would be unaffected. On the undulatory theory, however, this was the reverse of what would be anticipated.

Experiments of the kind illustrated afforded, Sir Joseph continued, one piece of evidence in favour of a corpuscular constitution of light ; another was derived from the effects produced when light of less than a certain wave-length was passed through vapours. The effect was to make these vapours conductors of electricity. This the speaker showed by passing the light of an arc through quartz windows and into a quartz vessel filled with vapour of mercury. A plate placed in this vessel was connected up to a charged electroscope, and it was shown that the action of the light was to cause a rapid loss of charge. When, however, a thin piece of glass was interposed in the path of the beam of light, the discharge ceased, since it was only ultra-violet light which had the property of making the vapour a conductor, and this light was stopped by the glass. Accurate measurements, the lecturer proceeded, showed that the effect on the vapour appeared quite suddenly with a certain definite wave-length in the light. It could not be produced by ordinary visible light, however intense, and the action of the most powerful arc had no effect if its light passed through glass on its way to the vapour. To be effective the wave-length of the light must be less than a certain definite value. With light of the proper wave-length, however, the conductivity produced was proportional to the intensity of the light.

This again could be explained on Newton's view. To make the gas a conductor a certain energy was required to knock out negative particles from its atoms. An "ultra-blue" corpuscle had sufficient energy to do this, but a "red" corpuscle had not. The fact that there was no effect whatever the intensity of the light, if of wrong wave-length, was, on the other hand, very difficult to explain on the undulatory theory.

Further evidence in favour of Newton's view was provided by a study of the ionisation of gases by Röntgen rays. These rays were a variety of light, but owing to their very short wave-length their effect in rendering gases conductive was very pronounced. Experiment showed that the phenomena followed a very simple law. The earlier experiments indicated that if the whole of the Röntgen rays were absorbed in a gas, the number of charged particles produced was independent of the nature of the gas. In short, so long as the rays were completely absorbed, the number of negative particles produced was the same, whatever the absorbent used. Guided by these observations, the speaker had put forward an explanation of the phenomena. Subsequent experiments had, however, shown that the law was not accurately fulfilled in the case of certain gases, but still more recently Barkla had proved that if expressed in one way the law was perfectly true. Under the action of Röntgen rays the molecules of the gas acted on emitted negatively-charged particles, which had a very high velocity, and these negative particles were the primary cause of the conductivity found. This conductivity was not due to the direct effect of the Röntgen rays, which merely caused a small number of molecules to expel these high-speed electrons, and these then ionised the gas and





made it a conductor. Barkla had proved that the number of these primary high-speed particles produced by a given beam of Röntgen rays was the same whatever the gas acted on, provided that in in each case the rays were completely absorbed.

With this proviso, whether the gas acted on were hydrogen or the heaviest known, a primary electron appeared in the gas for every "unit" comprised in the bundle of Röntgen rays. This was exactly the kind of evidence which was thought convincing in proving the existence of "atoms of electricity" in electrolysis, and it was equally forcible in proving the molecular constitution of the Röntgen rays. Each high-speed electron produced by the latter was thus, in short, accompanied by the disappearance of some unit in the Röntgen rays.

In considering such matters a mechanical model was often of assistance, and the Röntgen-ray unit might perhaps be looked upon as a line of electric force in the shape of a complete circle which moved through space with the velocity of light. The direction of the force being tangential to the line, the component in the direction of the motion would have a periodic character varying according to a sine law from plus in front to negative behind. If this unit approached a neutral atom, which was a doublet consisting of a positive lying adjacent to an equal negative charge of electricity, the interaction of the two would be somewhat as represented in Figs. 5 to 8. The moving circular line of force would bulge out as indicated in Fig. 6, while the line of force between the two charges would bulge upwards as indicated. At a later stage the two would meet as in Fig. 7.

There would thus be a tendency for the ring to break at the point D, and this break would take place if the electric force in the ring were stronger than the electric force between the positive and negative charges in the atom. We would thus get the condition represented in Fig. 8, the negative particle being torn out and shot off at great velocity. In this process the Röntgen-ray unit would evidently be broken up and disappear, its energy being transferred to the electron which it had caused to shoot away. On the other hand, if the force in the ring were less than that uniting the di-pole, the ring would wriggle free and go on unchanged. The process above described could be reversed, and a Röntgen-ray unit produced from a cathode particle.

Similar ideas would apply to ordinary light, of which a Röntgen ray was only one form. Such units as described would take the place of Newton's corpuscles, and all would proceed swimmingly so long as we had only to deal with electrical phenomena. The trouble came in when we had to explain other properties of light. Thus optical phenomena required the existence of a regular sequence of such units extending over, say, 100,000 periods. On the other hand, the natural view was that all such units would be independent of each other, and in that case it was difficult to see how the necessary regularity of phase was to be provided if light were due to the ejection of units of this kind.

The speaker's view was that the necessary regularity of phase was imposed on the units by the medium through which they travelled. Only those particles which showed the necessary regularity would get through, the others being sent back till they had learnt to arrive in the right phase. In this connection a remark made by Stokes had been far too frequently ignored. Stokes observed that, to get refraction, the vibrations must continue for a considerable time. The first few vibrations received should go straight through the medium without being refracted, and refraction would only arise after something had been set swinging in the atoms of the refracting body. This idea was applicable to light units of the nature sketched above. Suppose that something in the volume of the body was set in vibration by some light unit which had just fallen into it, disturbing the electric field of force in the atom. If another light unit came up with its field of force parallel to the then instantaneous direction of the electric force in the atom, it would get through without difficulty. If, however, the two fields were in opposite directions, and that of the atom were the stronger, the light unit would be repelled.

For example, on the electro-magnetic theory of light, if the vertical (Fig. 9) denoted the direction of the electric force in light, and the horizontal that of the magnetic force, the direction in which the energy was propagated was at right angles to both forces, and in the case indicated would be out from the paper. If the electric force were reversed, the direction of the flow of energy would also be reversed. Hence when a unit of light came up to an atom disturbed by the passage of a predecessor, it might find the electric field inside the atom opposed to its own field, and would consequently fail to get through. Any violent difference in phase would thus give rise to a sorting out of the particles. If exactly in phase they would get through without difficulty, but otherwise be repelled, to come back again as the opposing force fell off. They would, so to speak, keep knocking and knocking at the atoms of the medium until the conditions were such as to permit of their passage. In this way the medium would impose on the light units a regular sequence of phase. The particles could not, in short, get through as a disorganised crowd, but must keep in step, the resultant uniformity being therefore imposed by the medium, and not impressed on them by their source. On this view the latter kept on erupting units irregularly, which were afterwards drilled into step by the medium.

Along these lines he thought it would be possible to obtain the uniformity required in optics, and to still retain the units, the existence of which seemed necessary to account for the electrical effects.

In this connection he would observe that, in order to explain certain optical phenomena, Newton had been led to endow his corpuscles with "fits of easy transmission" and "fits of easy reflection." If the corpuscle met the surface of a medium during a fit of easy transmission, it passed through, and in the contrary case was reflected. On the rise of the undulatory theory a good deal of satire had been heaped on the arbitrary and artificial character of this conception, but on the electro-magnetic theory of light Newton's "fits" formed a just corollary to our conception of the way in which the energy was transmitted through an electro-magnetic medium. If light

came up to an atom and found the intrinsic electric field of the latter in the same direction as its own, the light would proceed in the same direction as before, and, in Newton's language, would be in a "fit of easy transmission." If, on the other hand, the two fields were oppositely directed, and the atomic field were the stronger, the light would be pushed back. Hence, taking the most modern views as to the transmission of energy in an electro-magnetic field, Newton's method was one way—and by no means a bad way—of describing the process.

In some such way as the foregoing, it would, Professor Thomson concluded, be possible to retain the essentials necessary to explain optical effects with the atomic constitution needed to account for electrical phenomena.

NOTES.

The Society of British Aircraft Constructors.

Every day brings new evidence of the immense importance of aircraft in warfare, and suggestion of the necessity for the co-ordination of skill in design and manufacture, and for the prosecution of a vigorous policy, in order that the ability, experience, and resource of aircraft constructors should be utilised to the fullest possible extent by the British Government and by our Allies. We say nothing here of the potentiality of aircraft for the transport of passengers when peace is restored, because that belongs to the future, which has great possibilities, not only in this, but in many other respects. For these reasons we welcome the organisation of the Society of British Aircraft Constructors, because the science of aeronautics is one which stands more or less by itself, and without such a society the great variety of scientific and technical institutions organised in this country would be incomplete now, as well as in the immediate future. Several of those existing societies deal in a somewhat nebulous way with this branch of science; but it is so important, and demands such concentration, as to establish a claim for a special representation amongst the "learned societies." The objects of the new organisation are commercial as well as scientific, but naturally, for the present, the latter must stand in abeyance, as the demand for secrecy regarding the work done in design and manufacture precludes any contributions or discussions of a technical nature at the proceedings of such an organisation. But there is wide scope for private conference, with the possibility of invaluable service in the direction of co-ordination in design. On the commercial side the advantages are no less important at the present moment, because there will be possibility of collective action to impress upon the authorities the necessity for utilising all our resources. The Society begins its career under the happiest auspices, as its membership already includes every company now engaged on aircraft construction, and these companies have nominated their experts to represent them at the meetings. Members may be individuals, partnerships or corporations nominating one of the members, directors or officers to represent them. The entrance fee is 30*l.*, the annual subscription 20*l.* Associate members are also to be elected, the entrance fee in their case being 15*l.*, and the annual subscription 10*l.* A council has been formed, with Mr. H. White Smith, of the British and Colonial Aeroplane Co., Limited, as chairman, and with eight other representatives of leading aeroplane construction firms. One interesting feature of the constitution is that the members of any branch of the industry (being members of the Society) may apply to the Council to form special trade sections for the investigation of scientific or manufacturing problems, and each sectional committee, with the full *imprimatur* of the Society, may carry out research or propagandist work, without, however, entailing any expenditure of the Society's finances. The Council, however, reserve the power of control in every respect, and, in any case, the appointment of the sectional committees is subject to annual revision. Local sections may also be created in provincial districts.

Atmospheric Corrosion of Copper-Steel.

The addition of copper to steel having repeatedly been recommended for the purpose of increasing the resistance to corrosion, a series of tests were made by D. M. Buck, metallurgical engineer to the American Sheet and Tin-Plate Company, of Pittsburg, and J. O. Handy, director of the laboratories of the Pittsburg Testing Laboratory. The copper percentage was kept within the limits 0.04 and 2; the influence of other elements, phosphorus, silicon, aluminium, sulphur, and of mill scale, was also investigated, and it was further thought advisable to mix cold steel turnings with the metal of one of the ingots. Some "pure iron," from another firm, was submitted to the same tests, which were carried out quite in a technical way, the operations of blooming, rolling, sheet-rolling, &c., being conducted according to regular mill practice. On the other hand, the tests, particulars of which are published in the *Journal of Industrial and Engineering Chemistry*, March, 1916, were restricted to atmospheric corrosion. The bars were taken from all parts of the ingot, and the sheets, of American gauge 26 (0.0185 in. thick), were 96 in. by 26 in., and annealed at 1400 deg. Fahr. (the usual temperature), or at 1600 deg. Fahr. From the sheets strips 2 in. wide were cut lengthwise and analysed. The carbon percentage was about 0.06 (limits 0.02 to 0.08), the manganese percentage was about 0.41 (0.60 maximum), sulphur ranged up to 0.14, phosphorus to 0.11, silicon to 0.123. The analysed strips were corrugated and exposed as roof panels, either in full length or subdivided into test-pieces of 2 in. by 4 in. The exposures took place at McKeesport and at Scottdale, in Pennsylvania, in and after July, 1914; both these towns are mill districts, but Scottdale is also a coke region, and the corrosion was decidedly worse there than at McKeesport. The specimens were examined every two months, or at intervals ranging from one to five months, the rust being removed by treating the specimen with ammoniacal solution of ammonium citrate, to ascertain the loss in weight; this solution practically does not attack bright iron and steel, but eats a little into the metal of rusty iron. The loss of metal was found to be very much the same with the different grades (24 grades of steel were tested), and the results were on the whole very concordant, also as to the loss of weight sustained by the large and the small specimens. Two grades of the pure iron were tested; they contained 0.013 per cent. of carbon, 0.04 or 0.05 of manganese, 0.03 of sulphur, 0.031 of oxygen, and 0.027 or 0.045 per cent. of copper; phosphorus, silicon, and aluminium were present in very small percentages; the sheets were a little thicker than the steel sheets, the thickness being 0.022 in. The pure-iron specimens were tested only in the Pittsburg atmosphere, and comparison tests with the other steels were also conducted there. As the pure iron itself contained copper, and nearly as much, moreover, as the other tests seemed to prove effective, the results are not really distinctive. It would appear that the presence of copper made the steel decidedly more able to resist atmospheric corrosion. In ordinary steel this influence showed already at 0.03 per cent. of copper, and the effect was almost at a maximum when the copper percentage was 0.05; for commercial steels 0.25 per cent. of copper would probably be best, though other tests indicated that nothing was gained by going above 0.15 per cent. Such 0.25 per cent. copper-steel (open-hearth or Bessemer) outlasted the pure iron (with 0.04 per cent. of copper), whilst ordinary steel with 0.05 per cent. of copper seemed to be equal to pure iron as regards atmospheric corrosion. The progress of rusting under the first rust-coat formed was more rapid in ordinary steel than in the copper-steel, and less rapid in the latter than in the pure iron. As regards the other elements, phosphorus also lowered the corrosion rate. Silicon had hardly any effect when present in very small proportion, but favoured rusting when its percentage amounted to 0.1 or 0.3 per cent. Aluminium seemed to be harmful; sulphur decidedly accelerated rusting. The addition of cold steel to the molten metal did not have much influence, but that influence was not favourable.

Personal.—We are informed that Mr. T. S. Hunter, M.I.S.I., consulting engineer and marine surveyor, of 14, St. Mary Axe, E.C., has been elected a director of Dudgeon and Gray, Limited, consulting engineers and naval architects, of 89, Aldgate, London, E.—Mr. T. G. Howes Thomas, consulting engineer and engineering coach, of 47, Victoria-street, Westminster, has been appointed to a position under the Ministry of Munitions of War. Letters addressed to 47, Victoria-street, Westminster, will still receive attention, but Mr. Howes Thomas will be unable to accept any private work for the duration of the war.

THE INSTITUTION OF MECHANICAL ENGINEERS.

An ordinary general meeting of the above Institution was held on Friday last, the 14th inst., at the Institution of Civil Engineers, Great George-street, Westminster, the President, Professor W. C. Unwin, F.R.S., occupying the Chair.

The late Mr. E. D. Leavitt.

The formal business of the meeting having first been transacted, the President said that members would remember that quite recently the honorary life membership of the Institution had been offered to Mr. Erasmus Darwin Leavitt, the eminent steam engineer of Cambridge, Massachusetts. The speaker much regretted to say that since then Mr. Leavitt had died, and the Council had felt it desirable to send to his daughter a letter of condolence, in essentially, the following terms:—"At a meeting of the Council it was unanimously resolved that an assurance be conveyed to you of our deep sympathy with you and with your sisters in the loss of your father, who had been a member of this Institution since 1883, and whose nomination as an honorary life member had only recently been made. We desire to express our appreciation of his services to engineering, particularly in relation to the branch of steam engineering in which he accomplished so much and was so great an authority."

Filtration of Water.

The paper down for reading and discussion was entitled "Theory and Practice in the Filtration of Water," by Mr. Walter Clemence, Member, of Shortlands, Kent. We commence the reproduction of this paper on page 391 of this issue.

Mr. J. Liddell Simpson opened the discussion. He commenced by exhibiting to members a drawing of the original filter that was made by his grandfather, in conjunction with his great-grandfather, as far back as 1830. Some years ago he had been fortunate enough to find this drawing, and had kept it. It was signed by James Simpson, then engineer to the Chelsea Water Works. The sand filtration originated with the bleaching firms in Manchester (where space was very valuable), who had to devise some method of filtering the water which they used in that district. The original intake for the filter, shown in the drawing, was where the Grosvenor-road Station of the London, Brighton and South Coast Railway now stood. Before the Act of Parliament which obliged the water companies to move out of London to Hampton, a very long intake had been installed, which went right out into the river, and the water was only allowed into the settling-ponds at certain periods of the tide. Certain old drawings showed the Newcomen engines in use there, and at that period the water was pumped into the Chelsea district through wooden pipes.

On the subject of mechanical filtration the speaker would say that some twenty years ago he used an American filter, the advantage of which was that where a water works existed pumping could be done through the filter, obviating the need for a double set of pumps, one to deliver the water on to the filter-beds, and another to take up the suction pressure and deliver it into the town. It was an interesting experience at the time, because he had been brought up to follow only on the lines laid down by the water companies of London, where sand filtration had been started, and where it had been developed, but had been since very little altered. Some years ago the question of additional storage at the York company's works had to be considered by Mr. W. H. Humphreys, and they found that, unless they could devise some means of helping their existing filter-beds, a tremendous expenditure would be involved in the building of new settling reservoirs and new filter-beds. After careful investigation, Mr. Humphreys had decided to adopt the Jewell filter. The original water works at York were laid out by Smeaton, but later on were designed by the speaker's grandfather, and sufficient depth had been left between the settling reservoirs and the filter-beds to allow the Jewell filters to be installed. The result was that the filter-beds themselves ran for a very much longer period—they did not require so much cleaning—and the mechanical filters did most of the work. Before delivering the water into the town, however, they passed it through the sand filters, so as to be quite sure that the traditions laid down were not inter-

fered with. When in the States, the speaker had seen a great number of water works where mechanical filters had been adopted in preference to sand filters, on account of cheaper first installation and greater convenience in running. In the speaker's view, the question was largely one of whether there was the space in which to put down the slow sand filters on the lines so well known, or whether, in the case of water works that must have the increased quantity of water required for town service, it was necessary to utilise the space that was available. When the French went in for filter-beds and supplying the outer part of Paris (taking Paris for an example) with water drawn from the Seine, the question of the filters existing all over the world had been investigated, and, as he understood, the conclusion had been arrived at that if a lot of the preliminary work were done by pre-filters, the filtering could be carried out at about double the rate for the sand filtering practice ordinarily followed in this country. A modified form of filter was therefore adopted, and it was easy to see that, with double the rate of filtration through the ordinary sand filters, a very much larger quantity could be passed through the same space. Going back into the history of filtration it was interesting to know that the value of the film on the beds as a filtering medium was well understood, but until Dr. Koch investigated the bacteria and went into the theory the matter was taken for granted and not much looked into. What was really the theory of filtering was laid down by the Germans, who were very precise in running their filter-beds and investigating anything to do with water supply. Now, however, the French were going into the matter from their point of view, and establishing as an outcome that by using pre-filters a very much more economical plant could be installed in the first place, with just as good results as with the old sand filters. The speaker was much interested in the paper, and thought it should be interesting to all engineers to note that a good many mechanical pumps and plants had to be used in connection with the modified filters.

Mr. Percy Griffith was the next speaker. He did not think he could add much information from his personal experience, but he felt that it would be of interest if the subject could be dealt with on somewhat general lines, in order that lessons might be learnt from general application. He had had some little experience of the mechanical filtering to which Mr. Clemence had referred in rather uncomplimentary terms; and while he would support Mr. Clemence's criticisms, he was not prepared for a general condemnation of that type of filter. In his own case he had had to deal with underground water from a boring highly charged with fine sand and something like silt; the sand was in contact with the bed of clay, and the attrition caused by the water effected a mixture which rendered the sand unpleasant to look at and difficult to extract. His impression of the effect of mechanical filtration was originally derived from the glowing accounts published by manufacturers, but he found that the efficiency of these filters was much less than those suggested; however, his clients were better off for having them. The filters afforded a very useful indication of the accumulation of sand in the water, and were thus a kind of safety-valve, to prevent the water from being pumped into the reservoir in that condition. As the author had pointed out, its efficiency was practically nil until the film was formed; the film immediately caused back pressure, and the rise of pressure indicated the limit of capacity of the filter. The author had stated that the mechanical filter was inefficient, yet equally costly to instal and to operate as an ordinary sand filter. Notwithstanding the speaker's experience, he could not condemn the system so drastically; the paper, moreover, contained no conclusive evidence confirmatory of such drastic criticism. The film, as Mr. Clemence had mentioned, was the centre of interest. But the author had contended that, except at very slow speeds of filtration, the effect of the film was purely mechanical, and had no bacteriological influence on the water; on this point the speaker would expect some contrariety of opinion, and was not convinced that the contention had been proved. He had himself tried coagulants, and had found their use objectionable for several reasons, such as their appreciable cost, the loss of head involved, with more or less proportional loss of efficiency up to the maximum loss of head; also the practical difficulty of constantly maintaining a proper proportion of coagulant, an excess being as objectionable as an insufficiency; further, the sentimental objection to the dosing of the public water supply with chemicals. The speaker was convinced that the public would be favourably influenced if the author could, in every instance, attach to the results of the system he advocated the words "no chemicals used." Mr. Griffiths had seen the installation in Paris, and had been impressed with its general efficiency and the scientific method of design. He did not consider that the four instances given by the author enabled the efficiency of the results to be judged, as these results were not very complete. Taking the Magdeburg case, the percentage of reduction of bacteria was given, and the method of calculation was known; but a defect inherent in the calculations was this, that while any bacteria were left there was no means of proving, except by special analysis and examination of the culture, whether any of the remaining bacteria were or were not dangerous. Even the small percentage mentioned by the author as the average reduction of bacteria—to 0.013 per cent.—coupled with the figure 18 in the second column, left a possibility of danger. In that instance, the albuminoid-ammonia and free-ammonia tests had also been referred to, and the results were more complete than in any of the other three cases; yet it would be admitted that these results afforded no convincing proof of the absolute and complete efficiency of the system of filtration in question. In the case of the Derwent Valley installation the speaker would have liked more information as to the reasons which led to the adoption of this system for a special purpose. It was noticeable that the treatment was not the ordinary purification treatment, but treatment to remove acidity and also colour. The speaker believed that the application of the system to these purposes had never before been made. With regard to the Accra plant, the only notable test was the albuminoid-ammonia test, which was, of course, very useful. In such a climate the reduction of disease was the most practical test that could be applied to water supply. The speaker considered that the tables given in the paper in connection with the Cawnpore settling-tanks were not quite clear; it was not easy to recognise that in every case the figures represented total solids, and for the benefit of the casual reader this should be indicated more plainly. He also thought that the "total solids" test was a very partial one in relation to the ultimate purification of water. The author had himself suggested a standard speed for filters in lineal feet per twenty-four hours or per hour, and the speaker thought this should be adopted in all cases; and where, in the paper, the old notation in gallons was given, it would be convenient if the equivalents in lineal feet per hour could be added; this course would simplify comparison. Mr. Clemence had referred to the thriving of organisms in high temperatures, and had given examples of installations in hot countries, such as those at Cawnpore and Accra. The speaker would inquire whether the high temperatures prevailing there had any effect upon the results of filtration and the operation of the filtering system generally. Finally, he would suggest that it would be interesting if comparisons between multiple filtration and slow-sand filtering could be expressed more commercially; that was to say, the results of some standard form of analysis—if such could be accepted—presented, and then the capital cost and working expenses. Such a practice would furnish a useful guide to the value of any particular plant, and facilitate comparison, on more definite and commercial lines, of competitive systems, such, say, as multiple filtration *versus* the mechanical filter.

Mr. H. T. Rutter criticised the title of the paper as too wide to do justice to the subject it covered. He thought a more appropriate title would be "The Puech-Chabal Multiple Filtration System." He had no wish to say anything against a system admirably adapted to the purpose to which it was applied, but desired to offer criticism of some of the statements in the paper. In the interests of clearness he would draw attention to an observation made, quite early in the paper, to the effect that the removal of the impervious layer had long been recognised as one of the greatest drawbacks to slow sand filtration, yet the theory became established that the efficiency of the filter as an agent for the purification of water depended almost entirely on the layer of slimy mud which had been observed to form on the surface of the filter after it had been brought into use. The speaker would substitute for "the theory became established" the words "the dogma became established, and was for a time generally accepted." It was quite true that a very large percentage of the bacterial contents of water filtered through a sand filter were removed at or near the surface, but it was not true that the bacteriological effect of the filter ceased at that point. The author himself a little later in the paper remarked: "Careful experiments by Reinsch and others have shown that in ordinary sand filters, having a depth of about 3 ft. of sand, the number of bacteria found in samples of water drawn at various depths in the sand-bed is gradually reduced from top to bottom." That, the speaker stated, was known before the beginning of this century by actual inspection of samples of the filtrate at various depths below the surface. The colloidal envelope which, after proper ripening of the filter, surrounded each grain of sand for practically the whole depth of the bed had, in the slow sand filter, an immensely important function, although it had to be admitted that a considerable proportion of the bacteria was removed at or near the surface. After all, the Puech-Chabal system did, in the central stages, what was done by the slow sand filter in two stages. It was in the nature of the case that prolonged storage and subsidence should precede the passing of the water on a slow sand filter. The first of the two functions, the removal of a considerable proportion of the solid contents of the water, was fulfilled, in the Puech-Chabal system, by degrossisseurs—the speaker would prefer an English equivalent for this word—but he would not like to affirm, without more evidence, that their action was as safe and trustworthy as that of light, air, and other agencies operating in the case of prolonged storage of water. The author was, he considered, inclined to lay undue stress on the more favourable cost of working claimed for the Puech-Chabal system. There was, of course, much to be said for the claim, but the paper did not furnish the necessary data upon which to base it; there were only statements to go upon, except in the case of the Cawnpore installation, and in that instance the results were complicated by the circumstance that the climate was tropical, and therefore it was impracticable to deduce figures which would be helpful when dealing with installations in more temperate climates. Mr. Clemence had submitted a contrast between the cost of cleaning the old sand filters, through which the water was previously filtered, and the cost of cleaning the pre-filters in the case of the new plant. But the cost of cleaning the old sand filters would be regarded as ridiculous in a temperate climate; the fact that the filters were blocked up after 4,000,000 gallons had passed through an acre of filter rendered any comparison with the records in more temperate climates absurd. The blocking of the Cawnpore filters was no doubt due to the enormously active growth of algæ as a result of sunlight and high temperature. If, however, the cost of cleaning the pre-filters at Cawnpore be taken, the figure arrived at would not be far removed from a reasonable figure for the cost of cleaning slow sand filters in temperate climates. The speaker admitted that the adoption of the Puech-Chabal system in the cases submitted by the author was justified; the system had, in all the cases, admirably adapted itself to the results desired, regard being had especially to a climate where the water was impregnated with the results of vegetable decay, absolutely needing oxygenation and re-oxygenation to effect decent filtering. With many of the remarks made by the author on mechanical filtration the speaker was in thorough agreement. Towards the close of the paper Mr. Clemence had referred to methods of water purification which the speaker regarded as "heroic"—namely, the use of ultra-violet rays, ozone, &c., and had further alluded to the misleading character of the results, as measured in microbes per cubic centimetre of sterilised water immediately after the apparatus had been in action. The speaker agreed with the author's views, and felt that results of that kind would be more interesting if tests were made some hours after the treatment, at a distance of perhaps a few miles from the point at which the water first entered the main, or after some few hours' storage in covered reservoirs.

Mr. Bertram Blount was the next speaker. He was glad to speak on the paper, as he had had something to do with the water at Accra, as well as other tropical waters. He had read the paper

with attention and had derived much instruction from it. He would confine his remarks to the question of tropical waters, of which Accra was a type; such waters were familiar to most people, but not to everybody. They were contaminated with the products of decayed tropical vegetation, the removal of which was an extraordinarily difficult matter. As Mr. Clemence knew, the installation at Accra had been put down on the advice of the late Mr. Walter Hunter, and the description given in the paper represented, he believed, the actual system. The method was that of multiple filtration with dégrossisseurs, or "roughing filters," as he would call them, through which the water passed with more or less satisfactory results. When the speaker was advising about the Accra water supply, he took the course that he had taken when advising as to the water supply at Mauritius, Nairobi (Uganda), Segundo, and other places. In all those cases he had found that the methods of filtration, however elaborate, well-designed, and systematic, were futile, and he sincerely hoped that the present attempt at Accra—in which he had collaborated with Dr. Simpson and the late Mr. Hunter—would have a better result, although he confessed that he did not believe it would, and that what had occurred at other places would occur again. The reason was this: The vegetable matter which came from the rapidly-growing and rapidly-decaying tropical material in water supplies like those of the Densu and similar rivers was not amenable to pure filtration, but, from many experiments, he had found it amenable to chemical treatment. There existed a prejudice against chemical treatment, which was looked upon as almost immoral. The author had made an eloquent case against the use of precipitants, and in this the speaker agreed; they were only coagulants, and if the material to be removed could be removed by other means it was far better. When, however, a material could not be oxidised by ordinary processes, but could be oxidised by a simple chemical, that method might be used. In the particular instances which he had cited he had found it the simplest course to use a catalyst in the form of iron, ferric oxide, or ferric hydroxide. Air was blown in as in the ordinary Anderson process, as modified and put into modern practice. That course was not only effective, but was the only effective method the speaker had ever found for waters of that character. When returns were made of the results of treatment at Accra and at other places, they might stultify the speaker. He much wished that would be so, but feared they would not. He would, in conclusion, emphasise the fact that there was a broad distinction between the tropical waters of which he had been speaking and the ordinary dirty river water, like that of the Seine (at Choisy-le-Roi), and the dirty water of the Thames, which could be, and were, treated satisfactorily by methods of filtration carefully worked out in the way Mr. Clemence had described, or the sedimentation processes, so successfully employed, with filtration afterwards.

Mr. Leslie C. Walker was specially interested in the paper, as he came from the town where, as he claimed, pre-filtration, or multiple filtration, originated. His father, the late Mr. Alex. T. Walker, had been the patentee of that system, and had designed and constructed multiple filters in the year 1890, the system being patented in 1893, and having been in successful operation ever since. His father had also been the patentee of a special drainage block for the bottom of his multiple filter, recognising the advantage of securing a uniform flow over the whole area of the filtering medium. The resulting multiple filters consisted of a series of gravel beds arranged in tandem, through which the river water passed antecedent to sand-beds of the orthodox type. Each set of filters consisted of five water-regulating and cleansing chambers alternating with five chambers containing the varying grades of gravel or other clarifying media. The depth of the latter was, in each chamber, 3 ft., and the sizes of the chambers were commensurate with the work required of them. The water antecedent to the sand filtration had therefore to pass, in downward flow, through a total depth of 15 ft. of clarifying media, and was then conducted, by distributing channels, on to the sand-beds. The preliminary purification thus effected removed 97 per cent. of the bacteria originally present in the river water, and the speaker believed that was a result which would compare favourably with that obtained by the settlement of the river water in costly storage reservoirs, while, under such conditions, it followed that the resultant work thrown upon the sand-beds was considerably reduced. The speaker accordingly agreed with Mr. Clemence that there was much to be said for the multiple system of pre-filtration. With regard to mechanical filtration, the speaker believed that this combination had proved highly satisfactory when worked in conjunction with the multiple filtration to which he had referred (or any other system of multiple filtration of a similar kind), and the injection into the clarified water of a minute quantity of free chloride, all traces of which could subsequently be removed by the interposition of a layer of carbon within the filter. Some remarks had been made in the course of the discussion about "doctoring," at the thought of which some people were generally horrified; it seemed to him, however, that the fact that nearly every liquid or food consumed was "doctored" had been overlooked by such persons. In respect to cost, the capital cost of sand filters, in conjunction with mechanical filters, was much more than in the case of mechanical filters in conjunction with multiple filtration. The speaker's experience showed sand filters to cost about 6000*l.* per million gallons and mechanical filters about 3000*l.* per million gallons per day, while the cost of the pre-filters, or multiple filters, was about 2000*l.* per million gallons per day. He had found the working cost of sand filters with preliminary filtration to be about 15*s.* per million gallons, while with mechanical or pressure filters the cost was about one-fifth, or 3*s.* per million gallons. The combination to which he referred had been in use for a very long time, dealing with river water, and, in the speaker's experience, had been all that could be desired. The water was frequently examined by bacteriologists like Dr. John C. Thresh, who had described the filters as producing a filtered water of the highest degree of purity, containing less than 10 bacteria per cub. cm., and no *B. coli* even in 100 cub. cm. of the final filtrate. The speaker could not avoid thinking, therefore, that the figures in relation to mechanical filtration quoted by the author must be the exception, rather than the rule. He would like to ask the author if he could reply to a question as to whether the Nottingham water supply (which he believed was obtained from the Derwent Valley Water Board) was passed through a system of mechanical filters recently put down, and whether mechanical filters were not also being put down at Leicester, another town which he understood was supplied by the Derwent Valley Board,

The President then called upon Mr. Clemence to reply, suggesting that he might amplify his remarks in the Journal later, as the time for closing the meeting had almost arrived. Mr. Clemence spoke for four or five minutes, and has since supplied us with the following extended report of his reply:—Some speakers had suggested that the paper advocated the use of a certain type of filter, and referred to mechanical filters generally in uncomplimentary terms. He wished to point out that, as far as possible, the use of proper names had been avoided with regard to the system of multiple filtration. Mr. Walker had every right to claim for his late father the credit of having been the pioneer in the use of the system in this country, although his application of it did not extend beyond the Reading Water Works. Roughing filters have been in use in connection with several large water undertakings in England for many years, and the author gained his first experience with multiple filters during an association extending over several years with the Antwerp Water Works Company. Careful experiments carried out at Antwerp by Dr. Kemna led to the construction, of which the author had charge, of a large installation designed for the purpose of clarifying the water while allowing the formation of a film on the surface of the final filters. Dr. Kemna has always been a strong advocate of the use of slow sand filters with a surface film.

Although Messrs. Puech and Chabal in their application of the system have always insisted on the necessity for preventing the formation of a film on the surface of slow sand filters, the author did not wish to suggest that they would be prepared to follow him in the theory of the action of a slow sand filter, which he had endeavoured to explain in the paper.

Mr. Liddell Simpson in referring to the York Water Works had stated that the mechanical filters which were there used as roughing filters, did most of the work, and that the open sand filters had been retained merely for the sake of tradition, but he did not produce any figures as to chemical and bacteriological results in support of his statement. The author had visited the works at York on more than one occasion and was quite familiar with the filtering installation and with the results obtained. The mechanical filters do not deal with the raw water of the River Ouse, but this is first passed through settling tanks, having ample capacity to allow of sedimentation of the water for 24 hours before it reaches the roughing filters. These undoubtedly complete the clarification of the water and effect a great reduction in the number of bacteria. But heavy growths of green algæ occur in the final filters, from which it must be inferred that the rapid filters do not eliminate the spores of algæ and that the water in the final filters is still heavily charged with organic matter in solution, as green algæ do not develop in the absence of organic matter. The final filters at York are unusually deep (10 ft.), and have a depth of filtering materials alone of no less than 6 ft. 6 in. As the speed adopted is less than 2 in. per hour, the water undergoes a treatment in the final filters of no less than 60 hours, which ought to, and no doubt does, bring about a high degree of purification in the final effluent. But, in view of Mr. Simpson's claim that the greater part of the work is done by the mechanical filters, it would be interesting if he would supply chemical and bacteriological analyses of the raw water of the Ouse at York, and of the same water after successive treatment by sedimentation, rapid filtration, and slow sand filtration. With regard to Mr. Simpson's suggestion that the ordinary speed of slow sand filters could be doubled if the water were first clarified, the author said that, so far as his experience is concerned, a speed of 6 in. fall per hour appears to be the extreme limit with such filters, even when these form part of an elaborate system of multiple filtration. Beyond this speed satisfactory results cannot be relied upon.

Mr. Percy Griffith had referred to the "back pressure" or "loss of head" due to the use of coagulants in mechanical filtration. This was the result of creating an artificial film on the filter. The natural film referred to by the author as forming on the grains of sand in slow filters had little effect on the "loss of head" in the filters even after these had been worked continuously for several months. Mr. Griffith had asked for further information as to the working of the four installations referred to in the paper, and as to the authority for the statement as to the results obtained given in the paper. The author pointed out that reference is made, in the text and in footnotes, to several articles and reports in which details of construction &c., are given. The information as to the working of the Magdeburg filters was supplied to the author by Herr Dieckmann, gas and water engineer of Magdeburg. The whole of the information as to the cost of construction and working of the filters at Bamford, and as to the results obtained, was given as received from responsible officials of the Derwent Valley Water Board.

The tables in Appendix II., relating to the working of the Accra filters, had been compiled from the reports of Mr. E. D. Course, Inspector Chemist to the Government of the Gold Coast Colony. The information relating to Cawnpore has been obtained from the official reports quoted or from the annual reports of the Sanitary Commissioner to the Government of the United Provinces of Agra and Oudh. The tables and the two diagrams relating to the Cawnpore filters were compiled from the carefully kept daily log-sheets of the water-works superintendent, copies of which were supplied to the author by Government.

Mr. Griffith had asked for further information as to the tables of "total solids" in Ganges water, and as to why no information was given as to the chemical results obtained. The author admitted that it would perhaps be better to refer to the results as "silt-by-weight" tests. The Ganges water was remarkably pure organically and bacteriologically, although usually turbid from the amount of fine silt carried down by the stream. The information asked for by Mr. Griffith would be found in the official reports referred to, which could be consulted at the India Office, London. Excellent chemical and bacteriological results were obtained from the slow sand filters at Cawnpore before the pre-filtration plant was constructed, and it was not supposed that the average results could be improved upon. The great difficulty experienced was the

rapid blocking of the filters by silt, and this difficulty has been entirely overcome.

Mr. H. F. Rutter had suggested that certain statements of the paper were contradictory, and said that the experiments of Reinsch and others were carried out in the last century, and that it was then known that the majority of the bacteria were retained on the sand grains at or near the surface of the filter. A certain number of bacteria were always found in filtered water, and the experiments referred to showed that only a small proportion of the bacteria which passed through the "filtering film" were to be found in the effluent. It was known that the vast majority of the bacteria in the raw water were retained in the organic film on the surface of the sand, and were removed with the film when the filter was scraped, leaving the filter inefficient. Puech's experiments showed that if the formation of the surface film were prevented, and the whole of the bacteria allowed to gain access to the bed, the number of organisms to be found in the effluent was actually less than the number to be found in water from filters on which a film had been allowed to form. This fact was certainly not generally known or admitted during the last century.

Mr. Bertram Blount had expressed the opinion that it would be necessary to treat the water at Accra with iron in some form before satisfactory results would be obtained with the multiple filters. The author wished to say that the question had received the most careful consideration of the late Mr. Walter Hunter who had great faith in the system of multiple filtration, but he had always been prepared to add the Anderson system of iron treatment if it should be found that the organic matters in the water at Accra could not be sufficiently reduced by filtration and aeration. Mr. Hunter was constantly consulted by the author on all the main features of the Accra installation when this was designed, and the experience in the use of iron and the application of multiple filtration on the same water at Antwerp, and the history of the application of the iron treatment there during a period of thirty years no doubt influenced the decision to try filtration alone in the first instance at Accra. It should be remembered that at Antwerp and elsewhere the Anderson system was always followed by aeration and filtration. The system was not successful with a soft water, and was abandoned at Antwerp owing to the fact that the hardness of the water was extremely variable (from 11.5 deg. to a considerably higher figure), and the results of the iron treatment could not be relied on. Recent analyses of the raw water at Accra showed that the hardness varied from 4 deg. to 8.5 deg. The iron process had also been abandoned at Agra, India, and was being superseded at Choisy-le-Roi, Paris, by prefilters.

The author wished to remind Mr. Blount that under unfavourable circumstances the filters at Accra had reduced the albumenoid ammonia content by nearly 80 per cent., as shown by the tables in Appendix II., and although the lowest figure was 0.012 parts per 100,000 against 0.008, the standard of purity set by Mr. Blount, he had sufficient confidence in the installation to hope that the degree of purification represented by the latter figure might be obtained. He had requested the Government to arrange, if possible, to run the installation at its full speed for one month, in order that its capabilities in the reduction of organic matters might be satisfactorily ascertained, and he hoped that the fears of Mr. Blount that it might be necessary to supplement filtration at Accra by the use of chemicals might turn out to be unjustified.

In reply to a question by Mr. Walker, the author said that he had no information as to the adoption of mechanical filters at Nottingham and Leicester. These towns derived a part only of their supplies from the Derwent Valley, and this water was filtered at Bamford in the manner described in the paper.

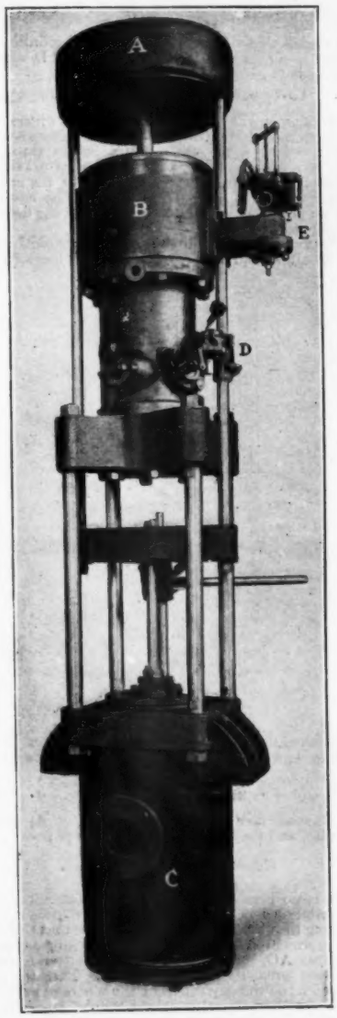
The President, in closing the proceedings, announced that there would be another ordinary general meeting, which would take place on Friday, May 19 next, when a paper entitled "Spur Gearing," by Mr. Daniel Adamson, would be read.

PANAMA MANGANESE.—An American syndicate which recently opened a mine of manganese ore at Madinga, Panama, has made a trial shipment of 900 tons to the United States. It is intimated that 1500 tons per month could be shipped if tonnage is available.

A NEW TYPE OF HUMPHREY PUMP.

WE illustrate on this page a new type of Humphrey pump, intended for general pumping purposes. In the original pump, it will be remembered, the cycle was maintained by the momentum of a long column of water, which oscillated to and fro in a horizontal play-pipe. This system is eminently adapted for large water-works and drainage pumps, but cannot always be conveniently installed. The pump we now illustrate is also a free piston pump, but the inertia necessary for the maintenance of the cycle is provided by a block of cast iron in place of by a long column of water. There is thus a great gain in compactness, which is further increased by the fact that the pump works on the two-stroke cycle.

The gas-cylinder of the pump is at B and the water-cylinder below at C. The method of operation is as



follows:—Conceive the gas cylinder with its piston at the bottom of the stroke, and a charge compressed below it. On ignition this piston is driven upwards, carrying with it the cast-iron weight A, which is coupled, it will be seen, to a cross-head on the piston-rod. At a certain point of the up-stroke the cam D comes in contact with a roller carried at the end of a bell-crank, the opposite end of which opens the exhaust-valve as the roller is carried up by the continued motion of the weight A and the parts connected therewith. The exhaust-valve being thus opened, the pressure inside the gas-cylinder falls to that of the atmosphere. The upward motion of the piston, however, continues in virtue of the momentum already acquired, and a little later the piston overshoots a series of ports communicating with an annular chamber surrounding the upper end of the working cylinder. Into this chamber the upward motion of this piston had previously compressed a charge of air and gas. This charge is now able to escape through the ports into the cylinder below the piston. The latter, continuing its motion, is finally arrested in part by the pressure due to air trapped between its upper surface and the top of the cylinder, and in part by the loss of momentum due to the raising of the weight A. It accordingly returns, compressing the new charge into the clearance space. At the end of the in-stroke the charge is fired, and a new cycle recommences. During the down-stroke of the piston a new charge is drawn in above its upper surface through the valve E.

To prevent accident in case of the exhaust-valve leaking or breaking, an air-cushion is provided between the under surface of the weight A and the top of the cylinder-head. To start the pump, the piston is raised, by the hand-lever shown, to the top of its stroke. A charge is then admitted below it. The piston is then released, and descending under the impulse of the weight A, compresses the charge, which is fired in the usual way. During this descent a new charge is drawn in above the upper surface of the piston, and the next stroke is made as in normal working. The pump we illustrate has a 3 in. barrel, and can deliver 3000 gallons per hour against a head of 33 ft. Working on petrol, it takes five-eighths of a pint per hour, and if run on gas the consumption is 20 cub. ft. per hour. Its total weight is 350 lb. Other sizes are made, the consumption of fuel being relatively less the larger the pump, and heads up to 172 ft. can be dealt with.

"ELECTRICAL POWER PLANTS IN THE THAMES."

TO THE EDITOR OF ENGINEERING.

SIR,—In your issue of the 7th inst. Mr. Dean frankly admits that he knows little or nothing about the fuel supply of London. Well, Sir, seeing that fuel is the principal item for the generation of electric current, I think that you will agree that this is the point that ought to be given the chief consideration as regards the question of situation of plant.

To place power stations where Mr. Dean suggested, and have coal taken there by his plan, would practically double the transit charges of the material from the colliery. Again, I doubt if the Port of London Authority would grant permission for the site; it is just the 100 ft. of the deepest part of the river, but there is also the possibility of craft being moored at all times to the structure.

I am no opponent of the centralisation of plant, as my previous letters will prove. It is the reduction of cost in producing electrical current that will give us a lead in the economical use of fuel by bringing in those manufacturers who generate their own power in a small way, probably only getting a third of the heating value of the fuel. Now, Sir, let us be a merry family, and welcome the gas-producing firms; we shall then be able to get everything possible from the coal, and each will be more than satisfied.

I have looked up Mr. Dean's first letter, and note his remarks as regards conveying current by tunnels. These tunnels to both sides of the river at "several express power stations" would be rather costly for the simple transmission of current and supply of fresh water, particularly when consideration is given to the stratum they would rest on.

The whole of this correspondence is directed with a view to the economical use of coal; but as it is too large a subject to go into in an ordinary letter, I refer you to a pamphlet I sent to you, written by myself to stokers and owners of steam plant.

I remain, Sir, yours faithfully,
JOHN H. ANDERSON.

Purfleet, Essex, April 10, 1916.

LABOUR TROUBLES IN WAR MUNITION FACTORIES.

TO THE EDITOR OF ENGINEERING.

SIR,—In June last year you published a letter that I addressed to you urging the necessity of vigorous Government action in dealing with shop stewards and others, who, it was pointed out, were generally the cause of the unsatisfactory output and the trouble that was occurring.

In view of what is now going on, the letter might be published again as a new letter, for all the change there has been in the last ten months. The general public, who are not closely in touch with engineering and shipyard work, might imagine that the recent occurrences on the Clyde are something new. But the situation is not changed, and the Government have not yet been able to make up their mind to treat these men who are causing the trouble in the way they deserve.

In my former letter I urged that it would be necessary to organise and discipline labour in a military sense, and I think those who are engaged in Government work will agree with me that it is more than ever necessary at the present time. The causes of the trouble, as I then explained, were all the result of local agitations caused by some few men in the different districts who acted independently of the head executive of the trade unions.

The men are still refusing to work with non-unionists, and are putting every obstacle in the way of employers taking advantage of the agreements which have been made with their head executives as to the removal of the ordinary trade-union restrictions. These men, unfortunately, succeed in exercising their bad influence over the workers.

A favourite excuse now, just as it was last year, for objecting to a man who is not a member of their trade

union is that he is not a good worker and they object to work with him. Firms who undertake the work, with their managers in conjunction with the Government overseers, are responsible that the work is properly carried out, and it is a monstrous position that these agitators should cause delays in work through making such trouble about non-unionists.

Foremen and managers were practically helpless last June, just as they are at the present time. They have been harassed with labour troubles for the last eighteen months, and in many yards have ceased to be able to exercise their proper functions of directing the labour to the best possible advantage. Where they have shown sufficient force and strength of character in doing so, strikes of various descriptions have taken place. As is well known, since the Government action for dealing with strikes was disclosed, complete cessation of work has not as a rule been resorted to, but there are all sorts of other ways of delaying work, such as refusing to work on particular jobs or refusing to work overtime, which is one of the most favourite devices.

Now, the men who have made this trouble have all the time been well known to the managers of the different yards. They are usually Socialists. It may be simply wrong-headedness on their part, but the country has been authoritatively informed that it is known that one of the enemy devices has been to subsidise agitators to cause labour trouble; and if these men are not actually traitors to their country, at any rate they are acting as if they were. We have a Defence of the Realm Act. Why is it not used to protect the country from them? In any other of the countries that are at war, whether enemies or our Allies, these men would not be allowed another moment to do more harm.

I suggest, Sir, that the matter is one that a technical paper of the standing of ENGINEERING might well give a lead about to the rest of the Press and the country, who necessarily cannot be so well informed on these matters.

Yours faithfully,

SHIPBUILDER.

"ON THE WHIRLING SPEEDS OF LOADED SHAFTS."

TO THE EDITOR OF ENGINEERING.

SIR,—The very careful investigations of Mr. Kerr on the above subject, recently published in ENGINEERING, merit every attention, and are quite correct in the experimental part and in the graphical determination of the critical speed. The calculations, however, which Mr. Kerr gives on page 225 of your issue of March 10, in following the lines pointed out by Dr. Chree, prove by closer examination to be fallacious. As the subject is of the greatest practical importance, and the logical error of a delicate nature, I think turbine-designers will have some interest in the following statements.

Let, in Fig. 1, O denote the position of the unstrained shaft, A the point of the intersection of the shaft with the disc after deflection, so that A O is proportional to the elastic force exerted on the disc. S means the centre of gravity, e the "eccentricity" of the disc. For simplicity, we shall suppose that the plane of the disc remains always normal to the original axis, whose projection is O. We consider the disturbed movement of the disc relatively to a space which rotates in the same sense as the disc with the mean angular velocity ω of the disc. In this space the co-ordinates of S may be x, y. According to the theorem of Coriolis, we must add to the real forces which act on an elementary mass $d\,m$ the inertia forces corresponding to the acceleration of the point of the moving space which lies in that mass point, and the well-known Coriolis force $= d\,m\,2\,\omega\,w$, where w is the relative velocity of the mass point. We suppose that at the beginning the gravity W had the direction of the y axis; therefore, after t seconds, its direction will form the angle $\omega\,t$ with the vertical. If m is the total mass of the disc, the equation of the motion of the centre of gravity will then be

$$\left.\begin{aligned} m\,\ddot{x} &= m\,x\,\omega^2 + 2\,m\,\omega\,\dot{y} - a\,(x+p) - W\sin\omega t \\ m\,\ddot{y} &= m\,y\,\omega^2 - 2\,m\,\omega\,\dot{x} - a\,(y+q) - W\cos\omega t \end{aligned}\right\} \quad . \quad (1)$$

where the point (.) means d/dt, and a is the factor with which it is necessary to multiply the deflection in order to obtain the elastic force.

We will consider the movement about the centre of gravity as a rotation with the constant angular velocity ω. The full investigation of the motion with a finite mass-inertia moment of the disc is an exceedingly complicated matter. If the effect of the weight were neglected, S would lie on the connecting line O A, in the position defined by:—

$$x_0 = \frac{a\,p_0}{m\,\omega^2 - a}\,;\quad y_0 = \frac{a\,q_0}{m\,\omega^2 - a} \quad . \quad . \quad (2)$$

We consider the movement in the proximity of this point, so that $p = p_0$, $q = q_0$ in putting

$$x = x_0 + \xi\,;\ y = y_0 + \eta \quad . \quad . \quad . \quad (3)$$

By introducing this in equation (1) and using the ordinary critical speed ω_k defined by:—

$$\omega_k^2 = \frac{a}{m} \quad . \quad . \quad . \quad . \quad (4)$$

we get:—

$$\left.\begin{aligned} \ddot{\xi} - (\omega^2 - \omega_k^2)\,\xi - 2\,\omega\,\dot{\eta} &= -g\sin\omega t \\ \ddot{\eta} - (\omega^2 - \omega_k^2)\,\eta + 2\,\omega\,\dot{\xi} &= -g\cos\omega t \end{aligned}\right\} \quad (5)$$

The simplest method of integrating these equations is to replace $\sin\omega t$ by $-i\,e^{i\omega t}$ where $i = \sqrt{-1}$, and $\cos\omega t$ by $e^{i\omega t}$, and retaining in the solution only the real terms. The solution may then be written in the form:—

$$\left.\begin{aligned} \xi &= C_1\,e^{i\omega t} + u \\ \eta &= C_2\,e^{i\omega t} + v \end{aligned}\right\} \quad . \quad . \quad . \quad . \quad (6)$$

where u, v are new functions of x, y. This leads to the general equations:—

$$\left.\begin{aligned} \ddot{u} - (\omega^2 - \omega_k^2)\,u - 2\,\omega\,\dot{v} &= 0 \\ \ddot{v} - (\omega^2 - \omega_k^2)\,v + 2\,\omega\,\dot{u} &= 0 \end{aligned}\right\} \quad . \quad . \quad (7)$$

and to the determinate equations:—

$$\left.\begin{aligned} (2\,\omega^2 - \omega_k^2)^2\,C_1 + 2\,\omega^2\,i\,C_2 &= -g\,i \\ -2\,\omega^2\,i\,C_1 + (2\,\omega^2 - \omega_k^2)\,C_2 &= g \end{aligned}\right\} \quad . \quad . \quad (8)$$

The determinant D of these equations is:—

$$D = (2\,\omega^2 - \omega_k^2)^2 - 4\,\omega^4 = -\omega_k^2\,(4\,\omega^2 - \omega_k^2) \quad . \quad (9)$$

and the solutions of C_1 C_2 will have, of course, the form

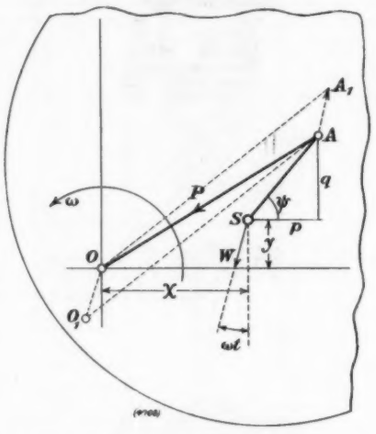
$$C_1 = \frac{A_1}{D}\,;\ C_2 = \frac{A_2}{D} \quad . \quad . \quad . \quad (10)$$

So it seems that we must, indeed, expect infinite values of ξ and η—*i.e.*, a "critical" velocity, when D vanishes, which leads to:—

$$4\,\omega_c^2 - \omega_k^2 = 0,\ \text{or}\ \omega_c = \tfrac{1}{2}\,\omega_k \quad . \quad . \quad . \quad (11)$$

This value of the "new" critical speed differs materially from that of Mr. Kerr, because he considers a motion in which S and A lie always on a radius through O, which is not admissible, as the centre of gravity has certainly 2 deg. of freedom. The effect of the contrary assumption of Mr. Kerr shows itself, as he has recognised* on page 246, in the steady growth of the deflection above the normal critical speed.

Unfortunately the value ω_c has no mechanical significance at all, as can be proved, firstly by finishing in a



mere arithmetical manner the determination of the quantities A_1 A_2. By solving the equations (8) we arrive at:—

$$A_1 = -(4\,\omega^2 - \omega_k^2)\,g\,i\,;\ A_2 = (4\,\omega^2 - \omega_k^2)\,g \quad (12)$$

which demonstrates that when D vanishes, A_1 and A_2 vanish also, and the limit values of C_1 C_2 are:—

$$C_1 = \frac{g\,i}{\omega_k^2}\,;\ C_2 = -\frac{g}{\omega_k^2} \quad . \quad . \quad (13)$$

There is no possibility for C_1 C_2 to become infinite.

The simplest demonstration of the true motion consists in choosing the unit of the elastic force w, so that this force will be represented by AO, and in decomposing AO in the components AO_1 and AA_1, so that the latter is always parallel and equal (but opposite) to W. Then the effect of the weight on the movement of the centre of gravity is annulled, as there remains only a couple, which causes very little oscillation about the centre of gravity, as the mass moment of the disc is always very great.

If we consider the natural movement with $O\,O_1$ as the direction of the vertical, the point O_1 remains fixed, as $O\,O_1$ must be equal to $A\,A_1 = W$, and the undisturbed movement of S will be a constant rotation, with O_1 as centre. The same is obtained analytically, for the absolute co-ordinates x, y, in using the equations employed by Föppl, which are, if $S\,A = e$,

$$\left.\begin{aligned} m\,\ddot{x} &= -a\,(x + e\cos\omega t), \\ m\,\ddot{y} &= -a\,(y + e\sin\omega t) - W. \end{aligned}\right.$$

By putting $W = a\,h$ and $y + h = z$, the second equation assumes the form:—

$$m\,\ddot{z} = -a\,(z + e\sin\omega t).$$

Hence the movement would be the same as if gravity did not exist, but for the new abscissa axis, which lies at the distance h beneath the old one. And there is no critical speed, except the ordinary one.

It is very regrettable that the elaborate analysis of Mr. Kerr, which I duly appreciate, has not proved to be the solution of this intricate problem. Indeed, I have had serious communications from builders of steam-turbines and turbo-blowers who have observed that there occur trepidations and noise at revolutions which are out of the range of the normal critical speeds. And a curious coincidence: one observed those phenomena when $w = \frac{1}{2}\,\omega_k$ (see fallacious equation (11)); another when $w = \omega_k/\sqrt{2}$. Of course, I do not know the special circumstances in which these observations were made; at all events, there is still a wide field for further research.

I am, Sir, yours faithfully,

Zurich, École Polytechnique Fédérale. A. STODOLA.
March 21, 1916.

* Which was also demonstrated by Mr. Blaess in 1914.

ENGINEERING EFFICIENCY.

TO THE EDITOR OF ENGINEERING.

SIR,—The letter from Mr. Chas. M. Darling on page 321 of the issue of ENGINEERING, April 7, recommending attention to greater engineering efficiency by the use of furnace-linings touches on a most interesting topic.

From experience gained in Australia I can say that furnace-linings have given general satisfaction, where properly applied, and more especially the furnace-linings of the carborundum type. In point of fact furnace-linings have been manufactured in Melbourne for some time, and the business appears to have every prospect of increasing.

Closely allied to furnace-linings, we find that boiler graphite of high-grade manufacture has contributed perhaps more than anything else of recent years to engineering efficiency, and owners of boilers would do well to inquire into the benefits derived from its use. Boiler graphite, being non-chemical in action, appears to fill a long-felt want; more so where the feed-water is of an inferior quality, and the results obtained more than pay for the cost of introduction.

There is one thing, however, which the manufacturers have not sufficiently brought to the notice of their clients, and that is that before the introduction of the graphite into the boilers *the boilers should be clean*; otherwise the graphite has the property of precipitating all scale, which is liable to bring about fatal results.

It would be safe to predict that when the benefits derived from its use become more widely known, boiler graphite will become a *sine qua non* where boilers exist—with the exception, of course, where the boiled water itself is required for cleansing purposes, such as hospitals, laundries, &c.

I am, Sir, yours faithfully,

J. DUNCAN BISHOP.

7, Hawcoat-lane, Barrow-in-Furness.

"THE FAN DYNAMOMETER."

TO THE EDITOR OF ENGINEERING.

SIR,—In a letter which is published in your issue of the 7th inst., Mr. Walker disagrees with my statements:—

(*a*) That for geometrically similar fans, the resisting torque varies as the fifth power of the linear dimensions.

(*b*) That the total resisting torque due to the fan can be taken as the sum of the resisting torques of the arms and the blades, each being calculated separately.

Mr. Waker's disagreement with (*a*) must surely be due to some misapprehension on his part. His disagreement with (*b*) is quite justified as far as it concerns the type of fan supplied by him; as in these fans the arms are made of wood and are very thick, and mask a considerable portion of the area of the blade.

If, however, the arms are made of steel, so that their thickness is only a small fraction (say, one-eighth or less) of the width of the blade, the resisting torques can, as I stated, be added together without sensible error. The experiments of Messrs. Morgan and Wood confirm my own work on this point.

In your summary of my paper the constant in the formula for the density of average atmospheric air was given (owing to an error in the proof originally sent to you) as 1.347. This should have been 1.317.

Yours faithfully,

J. LAWRENCE HODGSON.

Hydraulic Engineering Works, Biscot-road,
Luton, Beds, April 13, 1916.

MUNICIPAL LOANS FOR STORAGE BATTERIES. — We understand that, in response to an application made by the British Electrical and Allied Manufacturers' Association, the Local Government Board has agreed to extend the period for the repayment of loans in respect of storage batteries from seven to ten years, if satisfactory guarantees are given.

"LIVERPOOL SHIPPING."—The 1916 edition of this useful publication has recently been issued from the offices of the *Journal of Commerce*, 17, James-street, Liverpool. It comprises a complete personal and official directory to the shipping and allied trades in the ports of Liverpool and Manchester, and should be of much assistance to the shipping community, for whose convenience it was originally prepared. The greater part of the book is taken up with a list of Liverpool shipowners, lists of directors, historical and financial notes, office addresses, fleets and services being given for each company. Besides this there are lists of shipbrokers, societies and associations, insurance companies, and ship-repairers, as well as sections dealing with official and technical matters. Particulars of the docks are also given, together with folding plans showing those at Liverpool, Birkenhead and Manchester. The book is published at the price of 1s., or post free 1s. 3d.

NOTES FROM A COLLISION INVESTIGATION.*

By JOHN REID, Member.

ON May 29, 1914, the liner Empress of Ireland, in collision with the collier Storstad, capsized and sank in the St. Lawrence River. A Court of Inquiry was subsequently held at Quebec. Extracts from the official statement of the case to the Court are as follow:—"The catastrophe was very sudden; the Empress of Ireland received a very severe blow on her starboard side, struck by the starboard bow of the Storstad. She began to fill, turned over on her beam ends, and sank almost immediately; according to the estimate she remained afloat not more than 15 or 20 minutes at the outside from the time of contact." . . . "The nature of the damage which the Empress received cannot be proved; she disappeared immediately. Divers have been there, but I am informed that it is impossible for divers, owing to the fact that she is lying on her wounded side in the mud, to ascertain what the condition of the starboard side of the ship is, unless the ship can be raised, which I anticipate is impossible. Plans and details of the ship will be produced, and witnesses will be called to explain and comment on these phases of the case."

The writer was one of these witnesses, his instructions being to examine the damage sustained by the Storstad, and to endeavour to determine therefrom the exact place on the Empress's starboard side where contact occurred, the angle at which the two vessels met, the extent of damage, including depth of penetration of the Empress by the Storstad, and the behaviour of the two vessels subsequent to the collision.

From a preliminary study of the Stortad's bows it was easy to see that the damage to this vessel had resulted from an attempt to shoulder the luff of her starboard bow into the side of the Empress; but to determine, for example, the angle of contact of the Storstad with the Empress at the moment of collision, from the crushed and twisted wreck of the former's bows, did not seem very likely to prove an easy task. It might be mentioned that in matters of this kind the investigator is very apt to be biassed by preconceived theories, possibly derived from the reports of witnesses from either vessel, which are invariably found after a disaster of this magnitude to be quite irreconcilable. Then, again, there are everywhere distorted versions of the accident which create a veritable fog of error and misapprehension. There was, for example, a very prevalent impression, subsequently discovered to be incorrect, that the Empress when struck was lying motionless in the water, and that the collier struck the liner a blow approximately at right angles to her side, though, curiously enough, this impression was contradicted by another—viz., that the Storstad had struck the Empress a glancing bow, destroying an important transverse water-tight bulkhead. The writer will refer later to the idea, very prevalent after more than one shipping disaster, that rapid foundering is dependent upon, or the result of, a fore-and-aft ripping up of the side of the vessel sunk, thus explaining the failure of the water-tight bulkheads to justify the claims made by the builder or naval architect that a particular vessel will float with this or that number of compartments bilged. This theory seems to call for careful overhauling, because it may have led to quite erroneous conclusions from recent disasters, in which, as in the present case, it seemed at first impossible to decide precisely what had happened.

After careful study of the available data, the writer decided to determine, as nearly as possible, where on the side of the Empress the contact had occurred, and later to investigate the angle of contact, feeling certain that if these two questions could be handled successfully, the others could easily be disposed of.

A minute inspection of the damaged starboard bow of the Storstad indicated that the Empress, where struck, had stamped certain of its minor features upon the shell-plating of the Storstad's bow, in momentary contact with the Empress, before crushing took place. For example, the regularity of the vertical spacing of certain short horizontal scores on the damaged plating of the starboard bow pointed to the projection from the Empress's side of numerous small objects which were quickly recognised to be the snap-headed rivets on her topside plating. The traces of these rivet-heads also indicated that the first contact had taken place on the luff of the Storstad's starboard bow, and that this contact had been of very short duration before the crushing in of the Empress's side, and the simultaneous deformation of the Storstad's bow. The discovery of these rivet markings established another point of great importance. The most careful examination of the Storstad's damaged bow failed to show a sequence or recurrence of the markings, such as must inevitably have occurred if the Storstad had glanced along the Empress's side. It was clear that all the traces found had resulted from a single contact, followed by an immediate deformation of the shell-plating on which these marks were found. This disposed at once, so far as this case is concerned, of the glancing-blow idea, of which so much has been made in recent marine disasters. A first approximation to the point of contact with the Empress's side was obtained by the discovery on the port bow of the Storstad of a horizontal horseshoe-shaped indentation of very distinct shape; that is to say, so definite and regular a stamped-in effect as to justify the belief that it could only be the imprint of a particular feature projecting very prominently from the Empress's side. This belief was further strengthened by the fact that just above this prominent mark was the faint imprint of a sidelight frame. At this time no plans or model of the Empress were available, but the writer remembered having seen on the side of the Empress a series of protecting pads or rubbers projecting about 6 in. from the side of the vessel under each of the lower-deck coaling-doors, and ultimately this prominent mark on the port bow of the collier was attributed to the forward end of one of these pads. The particular one which had left this imprint was later determined from the Empress's plans by the discovery of the sidelight which measured the right distance from the pad corresponding to the imprints on the Storstad's bow. (See Fig. 1, below.)

Fig. 1. STARBOARD SIDE OF "EMPRESS" IN WAY OF DAMAGE

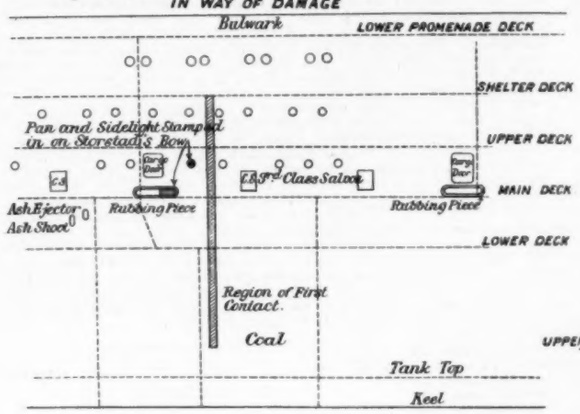


Fig. 2. "EMPRESS" OUTLINE MIDSHIP SECTION

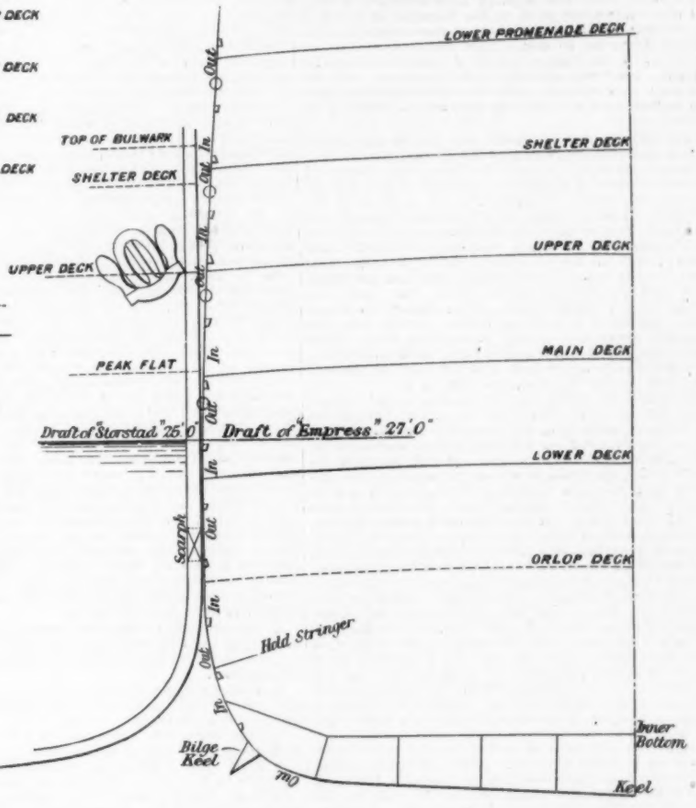
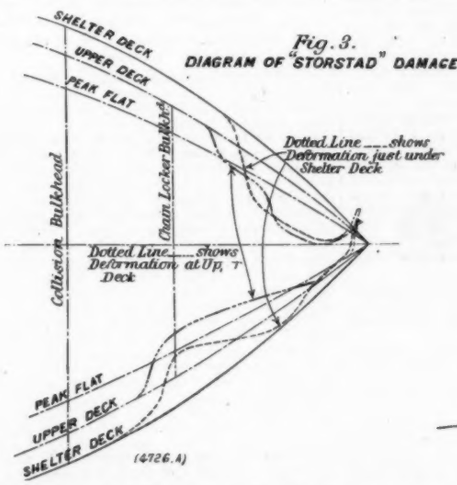


Fig. 3. DIAGRAM OF "STORSTAD" DAMAGE



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Unfortunately, these very helpful signs were imprinted on the port bow of the Storstad, and not on the starboard bow, where the first contact had certainly taken place; therefore the point of first contact remained to be decided. By a later consideration of the circumstances which attended the impact it was found that the imprints made by the Empress's pad and the sidelight on the Storstad's port bow represented the extreme limit of the aftermost damage to the Empress, and if, therefore, no glancing took place at impact, it was feasible to measure back from this aftermost limit to find the original point of meeting of the two vessels, and to determine this within limits of accuracy satisfactory for the purpose intended.

It was then found that this point of first contact was as nearly as possible 16 ft. abaft the water-tight bulkhead dividing the two stokeholds. The accuracy of this figure was cross-checked, so to speak, in a rather curious way. On the forecastle head of the Storstad some small wreckage, apparently from one of the cabins of the Empress, was picked up. This wreckage included a piece of wood with a number-plate on it, which was apparently from the state-room into which the bow of the Storstad had penetrated. This was found to be the door-plate of room 328, exactly over the place in the Empress's side already determined as the first point of contact, which was as nearly as possible amidships (Fig. 1).

To determine the angle of contact a process of elimination was adopted. It was, as already stated, generally

* Paper read at the Institution of Naval Architects, April 13, 1916.

supposed that the blow had been approximately at right angles. Any one who has made the slightest study of Bow damage is well aware that the bar stem usually fitted to merchant ships is a very poor article with which to deliver a blow square to the face of any substantial structure. The stem is drilled full of large holes, is poorly supported by its side plating, and is absolutely inefficient as a ram. The writer cannot recall a case in his experience where contact between the bar stem of one ship with another's side has not inevitably resulted in a fracture of the stem. The peculiar thing about the Storstad's stem was that, not only was it not broken, except short off above the forecastle deck, but it was not even scored across its leading edge, as must inevitably have been the case had it been subjected to violent contact with the Empress's shell-landing, stringers, and decks. Manifestly, therefore, an impact at right angles, or even approximately at right angles, in which the stem edge could have been brought into play, was quite out of the question. It seemed reasonable from these circumstances to assume that the bar stem had never done any cutting work at all; that the Storstad had crushed or shouldered the luff of its starboard bow into the side of the Empress, and that the stem bar had had no share in the damage done. But on such an assumption the angle of contact must have been under, rather than over, 45 deg., a conclusion quite at variance with the best evidence procurable. Actually it was found that this angle, measured, of course, between the centre line longitudinal planes of the two vessels, could not possibly have exceeded 40 deg., and that underwater parts of the Storstad damaged by the collision would call for an even more acute angle of contact down to 35 deg. This discrepancy may be accounted for to some extent by a heeling action under the blow, which was undoubtedly a very severe one, and may have careened both vessels through moderate angles. The actual nature of the contact was determined as follows:—

First of all, the Storstad's bow profile was drawn against the midship section of the Empress as if for a right-angle blow (Fig. 2, page 387). It was then discovered that the relation of the Empress's decks to those of the Storstad, at moment of contact, might be of great importance. It will be seen that the Storstad's stem at a right-angle blow would enter the Empress just under the latter's shelter-deck, which certainly sustained little damage; that the upper decks of the two vessels were approximately opposite each other, and that the main, lower, and orlop deck levels would also meet the Storstad's bow. Examination of the damage sustained by the starboard bow of the collier showed that the Empress's decks had stoutly maintained their shape against the penetration of the Storstad, that all of them, but especially the upper deck, left very definite traces of themselves on the Storstad, and had, in fact, to some extent turned the tables on the ramming vessel cutting deeply into its bow (Figs. 5 and 6, page 378). From measurements made from the traces of these decks on the bow of the Storstad on the assumption, corrected by later data, that the deck edges had not seriously deformed under the strain, it was easy to arrive at the conclusion that an angle exceeding 45 deg. could not be seriously entertained. Another check was obtained by a study of the wreckage on the Storstad's forecastle head. As already pointed out, this forecastle head had gone into the Empress just under the liner's shelter-deck, which acted as a plane, shaving away all obstructions, including the stem head, on the forecastle, right back to the windlass. As we have seen, this shelter-deck, not being subjected to any serious blow from the Storstad, would not deform. Had the Storstad gone fair into the Empress and backed fair out of the hole made by the collision, it would have been simple to find out accurately to a few degrees just what angle the contact had been at. All that would have been necessary would have been to draw a line across the forecastle head between the limits of damage on the port and starboard sides, and that would have determined the angle of contact and also the limits of penetration measured inwards from the shelter-deck stringer angle of the Empress. Also it would have been possible from such data to have very closely fixed the position and even the dimensions of the hole in the Empress's side from the same considerations. Unfortunately, the simplicity of such a line of investigation was marred by the discovery that the Empress could not have been stationary in the water at the moment of collision, as was generally understood. The catastrophe occurred in a fog, which tends to obliterate all ideas of time and space, and therefore also of speed, and it was quite certain that, after striking the Empress at an angle of under 45 deg., the Storstad's bows were held as in a vice, and the whole vessel swung through an angle of at least 100 deg. by a forward movement of the Empress through the water. Ultimately the collier's bows were withdrawn from the wound in the side of the Empress, but under these manœuvres the relation of the liner's shelter-deck edge to the damage line on the forecastle head of the collier underwent a change, and the angle of damage across the forecastle was only an approximate guide, owing to irregularities thus introduced. That some such swinging action had taken place after contact was quite clearly shown by the nature of the damage on the forecastle head, but it was indicated much more clearly by the peculiar damage formation on the Storstad's port bow.

It is necessary to turn back to a consideration of what happened at the moment of impact. It is probable that the first part of the Storstad actually to touch the side of the Empress was the forefoot, just where it turns in towards the keel-line (Fig. 4, page 378). The collier had a slight trim by the stern, which set the stem back from the perpendicular, and the Empress's side had considerable tumble home. These variations from the perpendicular make it rather difficult to state finally whether the overhanging luff of the Storstad's starboard bow or her forefoot made contact first. The point is not important, save as it tends to explain a peculiar double and contradictory tendency shown in the twist of the Storstad's bows. My explanation is that the collier's stem-bar got a momentary hold on the side of the Empress at the orlop deck stringer level, and that the stem started to go over to starboard, but before it got more than a start in this direction a different impulse met it, coming down from above, as a result of the meeting of the Storstad's starboard bow with the Empress's upper work. What happened was undoubtedly this. The collier had hanging in its starboard hawse-pipe a stockless anchor projecting several feet beyond the shell plating, which got caught between the upper decks of the two ships, which, as we have seen, met practically edge to edge. The blow was undoubtedly a very severe one, as is shown by the fact that the anchor was driven violently through the massive cast-iron hawse-pipe and forced inwards and aft through the adjoining bow-plating until it brought up at the extreme limit of the damage resulting to the Storstad from the penetration of the liner's side (Fig. 6, page 378). But this sudden blow on the side of the Storstad's bow, so near the stem, had a curious effect on the whole of the vessel's "nose." By "nose" I mean the stem-bar, the plating adjacent thereto, and the numerous small horizontal brackets or hooks which connect together the ends of the longitudinal frames. These hooks are only 2 ft. apart in the vertical direction, and the result of this construction is that the bow end of the Storstad is formed of a vertically-disposed girder of triangular horizontal section. It is this bow-end, or "nose," which turned over to starboard under the crushing action of the blow. First the blow high up just under the forecastle deck, due to the anchor being caught between the two decks which would not give way; then as the anchor was driven out of place and out of the way, this vertical bow-girder, which had started to turn to starboard on the crash, came up against deck after deck of the Empress as the penetration proceeded, and the whole bow went over to port, neutralising the conflicting tendency from below to go over to starboard. That some such action did, in fact, take place is indicated by the damage to the stem just above the forefoot, where the bend to port of the stem-bar is clearly shown and the scarph in the stem opened, allowing these conflicting tendencies to adjust themselves (Fig. 4). This turning of the Storstad's bow to port, and bearing in mind the fact that the direction of entrance into the Empress was at an angle from forward aft along the Empress's side, produced the result that the Storstad was caught by the "nose" and could not free herself immediately. She was, in fact, "hooked" into the Empress, and could only release herself as the liner moved ahead, when the Storstad swung aft and the interlocking parts freed. That the Empress was under way is shown by the crushing-in of the side of port bow of the Storstad just forward of the initial damage on this bow (Fig. 3, page 387). There is a double bay or indentation here, one formed by the turning over of the Storstad's "nose," as already indicated, and the other by the pressure of the after edge of the hole in the Empress's side, against which the Storstad hinged as the whole vessel slewed aft till she left the Empress stern to stern, having penetrated in the reverse direction. It was when this second bay or vertical indentation was developing that the pad and sidelight on the Empress, referred to above, were stamped into the port-bow plating of the Storstad, leaving a clue to the occurrence which proved most important. The main conclusions arrived at were then as follow:—

1. That the point of first contact was as near as possible amidships, the Storstad's stem entering just under bulkhead of Room 328 and forward of aftermost lower deck coaling-door.

2. That the angle of contact was very acute, certainly not over 45 deg., measured between the centre longitudinal planes of the two vessels.

3. That there was a penetration not exceeding 12 ft. from the vertical side of the Empress.

4. That the longitudinal bunker bulkhead of the Empress in way of the damage was not punctured.

5. That the Empress was in motion at the time of collision, but at a rate of speed which could not be accurately determined.

6. That the Storstad's "nose" going over bodily to port hooked her into the gap in the Empress from which she freed herself turning through an angle of about 100 deg.

7. That while the plating and framing of the Empress was immediately, under the influence of the blow, burst inwards and rolled back on the after side of the gap, the decks stood up to their work and resisted distortion in a very remarkable way.

8. That in a ramming collision longitudinal framing, as in the Storstad, shows very remarkable resistance to distortion by collapse. The damage to the Storstad, considering the nature of the accident and the consequences entailed, was almost trifling and did not extend to the collision bulkhead.

Conversely, the horizontal strength members of the Empress, such as the decks, "bit" very decidedly into the Storstad's bow between the longitudinals, and left unmistakable traces of the contact.

It would have been possible from the data obtained from the Storstad's bow to define fairly accurately the size and shape of the hole made in the side of the Empress. From this an estimate might have been made of the quantity of water per second entering the ship when the hole was free of the Storstad, but such estimates could serve no useful purpose, because the water entering could only find its way into the interior of the vessel through coal bunkers and bunker doors, and along the decks in a complicated way, permitting of no very accurate estimate of what action the inrush had upon the capsizing of the vessel, which ultimately consummated this catastrophe.

These notes are submitted by the writer to emphasise the great advantages which may be derived from a very careful study of the damage sustained by vessels from collision or any other cause, even such as mines, torpedoes, &c. At first sight it might appear that there would be no relation between the resulting damage from causes so dissimilar. The writer is convinced that there is the very closest relation. The inward thrust from, say, a mine exploding in close contact with a vessel's side is precisely the same as that produced by the blow of another vessel's stem with the concentrated momentum of a large vessel and heavy cargo behind it. In the one case you have a sudden sharp irresistible blow; in the other, a comparatively slow sustained but equally irresistible push. Whatever the inboard consequences may be, the outboard consequences to plating and framing are remarkably similar. In the neighbourhood of the impact a bursting in and setting back of the plating and framing, with a very determined effort of the deeper vertical and horizontal members to resist distortion. I refer to webs, stringers, decks, and bulkhead edges; it will generally be found that these portions of the structure form limits to the extent of the damage, looked at from the outside. It will, I think, be found that resistance to the sudden application of disruptive forces, from whatever cause arising, will be easiest obtained by a great increase in the number and depth of the frames, webs, and stringers under the waterline, just as ultimate safety after bilging must depend on a more minute sub-division into watertight compartments, involving a larger number of bulkheads, both transverse and longitudinal, than has yet been advocated. This, be it understood, only for the case of vessels of such size and importance from the number of passengers carried or the military value involved, as to warrant the increased cost and loss of deadweight or increase in displacement, as the case may be.

Finally, the writer ventures the opinion that watertight bulkheads, whether transverse or longitudinal, on which the safety of any vessel is based, ought not to be freely pierced as at present by doors, pipe passages, steam and exhaust connections, electric conduits, &c. To do so, no matter under what safeguards, is to destroy the validity of the bulkheads, and to vitiate all calculations based on their remaining intact.

THE MARINE DIESEL ENGINE AND ITS POSSIBILITIES.

*A Brief Summary of the Present Position of the Marine Diesel Engine and Its Possibilities.**

By Eng.-Lieut.-Commander W. P. Sillince, R.N. (Retired).

Present circumstances render it difficult to make a correct survey of the strictly present position of the marine Diesel engine, although this does not affect, to the same extent, the degree of accuracy (or inaccuracy) of deductions to be drawn, when considering the possibilities of the future. With a very few exceptions, the processes of evolution and development of the marine Diesel engine have, unfortunately, been carried out entirely on the Continent, and it is there that the largest experience has been gained and most progress made, to the detriment of progress in this country. One regrets to have to admit this. It is hoped that this state of affairs will soon be righted after the conclusion of the war, and there is little doubt as to this, for the British have a way of doing things thoroughly, although they may be rather late in making a start.

The marine Diesel engine is essentially an engine of detail. The failure of one or more essential details may involve very serious consequences. Also incorrect deductions may be drawn from failures of detail. For success and real progress there must be the most complete collaboration between the designers, the works, and the testing departments of any one firm of makers, and a frank and frequent interchange of ideas, through proper channels, between the various builders and users. Owing to the war, communications (particularly technical ones) have been rendered difficult with neutral, and necessarily impossible with enemy, countries. Also both ourselves and the enemy have for many months had to devote our whole attention to other things than the further development of the marine Diesel engine, and owing to the same cause there has been indirectly a retardation of progress in neutral countries. Therefore it may be taken, with reasonable accuracy, that the present position closely agrees with that of eighteen months ago. In considering the "possibilities," it is essential that full advantage be taken of a fairly accurate knowledge of past experience and progress to date, including failures as well as successes. In fact, the most valuable engineering knowledge is generally obtained from the experience of troubles surmounted than from cases of their complete absence. The process of acquiring such valuable experience is generally costly.

Apart from the difficulties, the present lull in the progress of development of the marine Diesel engine affords a convenient opportunity of reviewing past experiences and of surveying the present situation with a view to obtaining some indication as to the future. Although the subject of this paper precludes the consideration of the land type of Diesel engine, it must be said in justice that the marine type would not have attained its present state of development so soon had it not had the benefit of the results of years of experience with land types. The present paper has been prepared on the

* Paper read at the Institution of Naval Architects, April 12, 1916.

above lines, and is intentionally made as brief as possible, since it is intended to be more of the nature of an "indicator" than a paper of detail. The cycle on which the original Diesel engine of 1892 was intended to work was an "ideal" and theoretical cycle, having the highest thermal efficiency attainable with the large range of temperature proposed for the cycle. Economy was the keynote of the principle. Compression of air (air only, not a mixture of air, with gas and vapour) was for the first part "isothermal" (due to the injection of cold water into the cylinder), and after the supply of injection water was cut off, the remaining portion of the compression stroke was "adiabatic" (due to the lagging of the uncooled cylinder), with consequent rapid rise in temperature. At about dead centre, fuel (at first coal-dust) was injected into the hot air contained in the cylinder at such a controlled rate that combustion, which commenced at dead centre, continued during the period of injection at such a rate that the products of combustion expanded "isothermally." At a certain point in the stroke the supply of fuel was cut off, and the gaseous contents of the cylinder expanded adiabatically until, at the end of the stroke, they had expanded to, and were exhausted at, atmospheric temperature and pressure.

This theoretical cycle was very soon found too ideal to be a commercial proposition, and practical reasons led at once to a reduction in the ratio of compression, to the abandoning of water injection, to the water-jacketing of the cylinder, to the admission and regulation of the supply of fuel so as to give combustion at constant pressure, and to the exhausting of the products of combustion at a pressure and temperature both considerably in excess of atmospheric. The immediate results were a reduction of the maximum pressure in the cylinder and of stresses consequent thereon, a reduction of range of working compression temperature (still much more than sufficient to ignite any of the fuels used then or since), but they involved a large increase of temperature during combustion, and a considerable falling-off of thermal efficiency. There was, however, an increased output of power from a given size of cylinder, or, what is the same thing, a reduction of size for a given output. The use of coal-dust was abandoned, and liquid hydrocarbons adopted instead.

All Diesel engines of the present time aim at combustion at approximately constant pressure, are water-jacketed round the power cylinders, and exhaust at considerable pressure (say up to 40 lb. per sq. in. by gauge) and at a comparatively high temperature (say 500 deg. Fahr. and above). In regard to the processes happening in the power cylinders, there has been practically no change during the last fifteen years.

The first marine Diesel engines worked on the four-stroke cycle, and there are numerically many more marine Diesel engines in operation working on this cycle than on the later two-stroke cycle, which only dates from 1906. This is but a natural outcome of development, and the two types—viz., two and four-stroke cycles—will be compared later as we pass points in the paper. The earlier marine Diesel engines did not extend the cooling to the interiors of the piston crowns, being small in power; but, as sizes increased, it was found necessary to cool internally the piston with air, water, or oil (particularly so in two stroke engines), to water-cool the exhaust-valves, where fitted, and in some cases their seats.

As far as it has been possible to ascertain, the total number of Diesel-engined motor vessels completed to the end of December last is about seventy, having a total dead-weight capacity of about 350,000 tons, and a total brake horse-power of about 110,000. These vessels are nearly all of the cargo-carrying mercantile type; war vessels and submarines are not included. It is also understood that about a further fifty vessels, of over 300,000 tons dead-weight capacity total, and of nearly 100,000 brake horse-power total, were on order at the end of last year, and several large vessels of comparatively high power have been ordered during the past few weeks. When it is recalled that in 1911 the total number of motor vessels completed during that year was but three, of 5000 tons dead-weight capacity total, and 1200 total brake horse-power, it will be seen that progress has been extremely rapid in this type of vessel.

The engines fitted to these vessels are practically all of the single-acting, long-stroke, slow-running mercantile type, differing but little from the land type, except as regards reversibility, that they mostly have cross-heads, and that little restriction has been placed on weight or space occupied. The later motor-ships have engines, the powers of which range from about 750 to 3600 indicated horse-power per shaft—*i.e.*, from 125 to 600 indicated horse-power per cylinder. The fuel economy is remarkably good, the consumption varying from 0.3 lb. to 0.33 lb. per indicated horse-power per hour, or one-fourth to one-fifth that of good reciprocating steam machinery of corresponding size and type. The weight of the propelling machinery and self-contained auxiliaries varies from 3 cwt. to 5 cwt. per indicated horse-power.

A few of the larger engines work on the two-stroke principle, single-acting almost without exception, and develop up to 2500 brake horse-power (say 3600 indicated horse-power) per shaft, or 420 brake horse-power (600 indicated horse-power) per cylinder. The fuel consumption for this type is from 5 to 10 per cent. higher per unit of brake horse-power (due to the work required for scavenging), but per unit of indicated horse-power it is practically the same as for corresponding four-stroke engines. The weight per horse-power is about 25 to 40 per cent. less than for four-stroke engines; the space occupied is considerably less, especially as regards height. They are eminently more suitable to the higher powers than the four-stroke engine. At least one of the vessels is fitted with two-stroke double-acting engines of about 850 brake horse-power per shaft, or 280 brake horse-power per cylinder.

All the preceding figures relate to slow-running engines of the mercantile type. Apart from the above, there are at least three large experimental engines installed for testing on shore, designed for 2000 to 2500 brake horse-power per cylinder, of slow-running type, and suitable for propulsion; but although each engine has developed its designed power, the troubles experienced in two cases at least have been very great, and it is doubtful whether Diesel engines having such large powers per cylinder will ever be remunerative to their makers, or sufficiently reliable on service to justify their adoption on a large scale either for mercantile or naval purposes.

Generally, for naval work, engines having a relatively high speed of rotation, of light weight, and occupying as little space as possible, are required; and in many special cases these conditions are so vital that failure to comply prohibits their application. It is also desirable that the engines be made as robust as possible, and that reliability and fuel economy shall not be sacrificed unduly. The first high-speed naval type engine was completed about 1906, and since that time its development has been even more rapid than that of the slow-running mercantile type of engine previously referred to. The maximum powers per cylinder in high-speed engines at present at work are not so great as those of the mercantile engines, but the former are rapidly approaching, and may soon overhaul, the latter.

One is not permitted to state the numbers of vessels equipped with such engines, or to furnish more than the barest information about the engines themselves. Suffice to say that there have been constructed and set to work some hundreds of such engines, aggregating over 500,000 brake horse-power, the powers per shaft being generally slightly under 1000 brake horse-power, and the powers per cylinder varying from 100 to 150 brake horse-power. The speeds of rotation vary from 350 to 500 revolutions per minute. There are a few instances where the power is as high as 1500 brake horse-power per shaft, the power per cylinder varying from 125 to 250 brake horse-power. It is also known that in the summer of 1914 certain engines of submarine type, designed to develop 2500 brake horse-power per shaft, or over 300 brake horse-power per cylinder, were nearing completion, and they are now doubtless on service.

Quite recently an experimental single-cylinder submarine-type engine was tested on shore, and developed rather more than 500 brake horse-power at about 350 revolutions per minute. The reliability was said to be extremely good, as determined by a shop test of considerable duration, as was also the fuel economy. An eight-cylinder engine made up of such units would therefore give about 3200 brake horse-power per shaft, which exceeds the power per shaft of the largest mercantile engine at present built and installed.

All these high-speed engines are of the single-acting vertical type, the majority are "forced-lubricated." Rather more than half of them work on the four-stroke cycle, and the bulk of these latter are not reversible. As might be expected, those having the larger powers per cylinder work on the two-stroke cycle, and are directly reversible.

The weights per brake horse-power of this type of engine are approximately as follow:—For engines for continuous work, such as driving dynamos, 112 lb. per brake horse-power. For propulsion 84 lb. per brake horse-power for the smaller to 56 lb. in the larger units per cylinder. These weights refer to the engines themselves, including such accessories as lubrication and circulating-pumps, air-compressors, and reservoirs necessary to start and run them. In the small and medium sizes of high-speed engines, say, up to 800 brake horse-power per shaft, the saving in weight by the adoption of the two-stroke cycle is not usually very great, say, 15 to 20 per cent., but in the larger sizes the saving rises rapidly.

The fuel consumption per indicated horse-power per hour is generally somewhat higher than for slow-running engines, say, about 5 to 10 per cent., due principally to higher velocities through valves and ports, and more rapid "functioning," but this is not necessarily so. There is about the same disparity between the fuel consumptions of two and four-stroke engines of high-speed type as obtains between these cycles in slow-speed engines.

Owing to limitations of space, principally of head-room, this type of engine has hitherto been made single-acting only, and no crossheads or slipper-guides, in the ordinary accepted sense, have been fitted, although in certain designs the walls of the power-cylinder and their pistons have been relieved of the stresses due to obliquity of the connecting-rods, by fitting combined scavenging and guide-pistons beneath them. Naturally the wear and tear is greater in high than in slow-speed engines, but this is largely counteracted, at least as far as bearings are concerned, by the generally efficient systems of forced lubrication adopted in most high-speed Diesel engines.

In order that any Diesel engine shall render reliable service, it is necessary that certain essentials in design, construction, attendance, and maintenance shall be strictly complied with. As before stated, the Diesel engine is an engine of detail. In designing Diesel-engine details the particular function which the part is intended to perform must be most carefully considered in conjunction with the conditions under which it has to operate.

Essential factors to be taken into account, which do not, of course, all apply to every detail, are:—

(a) In Designing.

1. Adequate strength and stiffness.
2. Suitability of material.
3. Accessibility and ease of adjustment.
4. Satisfactory arrangements for the dissipation of heat and adequate cooling.
5. Absence of distortion under working conditions, during erection, and when replacing after examination or overhaul.
6. Sufficient, but not excessive, working clearances.
7. The results of experience on service should be rendered available for use by the designing staff.

(b) During Construction.

1. The use of suitable materials, particularly in castings subjected to heat or/and pressure, and those intended to contain fuel.
2. Accuracy in machining and in erection to ensure true form, correct fits and clearances, and preservation of alignment.
3. Absolute correctness of the timings, openings, and periods of all valves controlling air or fuel.

(c) Attendance when Working and Maintenance.

1. It is most desirable that the engineers in charge and their principal assistants be afforded an opportunity, during construction, of becoming acquainted with the details of the machinery which they will later have to handle, and with the working of the machinery during trials on shore.
2. Fully-detailed arrangement drawings and carefully drawn-up instructions (both for working and maintenance) are of great assistance in ensuring proper management, if followed.
3. Tampering with the adjustments, or alteration of the design of important details should be discouraged and prevented, at least until an expression of expert opinion has been obtained.

The principal reason for referring to the above points is that, owing to lack of attention to the points in question, each one of them has in some case or other (and sometimes in many cases) caused trouble or accident to the machinery when actually on service.

A few of the details which have given trouble, and which need special care and attention, will now be considered, with a view to facilitating the elimination of such troubles, and to point the way to further developments.

1. One of the principal difficulties has been the selection of proper materials for cylinders, pistons, and cylinder covers. As usually designed these parts must be castings. Many such intricate and costly castings in iron have failed owing to stress, irregular expansion, or inadequate jacket cooling. A case is on record where over a hundred cylinder castings were made before four good castings were obtained. This is, of course, a very exceptional case. Cast steel has been tried and has failed; "semi-steel," *i.e.*, cast iron containing a percentage of cast or wrought steel, is but little better; manganese bronze is being tried in some cases for covers, but its success is very doubtful; and the best material, so far, is a carefully selected grading of cast iron, having a very close grain, a high tensile strength, a small coefficient of heat expansion, and at the same time sufficiently fluid to completely fill the mould without undue internal stressing on solidification. It is doubtful whether the annealing of cast iron is of any real benefit, slow solidification and avoidance of chilling seems preferable, judging by personal experience. The difficulties above mentioned increase with increase of size, and any simplification in the design would be really helpful.

2. Frequent sources of trouble, which generally are located before an engine leaves its works, are directly traceable to inaccuracies of workmanship. Holes and bores which should be circular and parallel and made to certain dimensions are not so. Two such holes which in the engine are contiguous, and which should be concentric and coaxial, are not so. Efforts made to correct these inaccuracies of manufacture lead to still worse troubles: valves and spindles are bent, and may seize; the valves may remain open when they should be closed, and when in the closed position they may leak. This applies particularly to fuel valves, fuel-pump plungers, and air-compressor valves. Such cases aggravated by faulty alignment have also occurred with disastrous results in the main motion parts, *i.e.*, pistons, cylinders, and crossheads pin bearings. Crank-shafts have been received for fitting whose pins and journals were oval by more than the diametral working clearance permissible, and conical at that, whilst the crank-pins, instead of being in strict parallel alignment with the journals, have not only been inaccurate in two planes, but have been so disposed that the deviations in angular spacing have exceeded the limits of adjustment permissible on cams and valve gearing. Errors of workmanship which may be relatively unimportant under the low maximum pressures and temperatures obtaining in steam machinery are of the utmost importance in Diesel-engine work.

Passing now to the "running" conditions:—

3. The most frequent source of trouble at starting is "loss of air," and the obvious remedy is an efficient means of economising its use, a sufficient supply, and adequate auxiliary capacity for replenishment. Any economy, either in injection or starting air, is welcome, and skill, care, and experience in manipulation of the engine are the most important methods of securing this economy, particularly as regards starting air.

Sluggish starting may be due to insufficient compression owing to (*a*) piston ring leakages, (*b*) valve leakages, (*c*) wearing down of bearings, or (*d*) failure of fuel-pumps to "pick up" their fuel promptly, due to air locking, leaky valves, or incorrect "setting" as regards quantities. Each of these causes is readily capable of location and remedy if the proper steps are taken.

4. If the starting-valves are not operating as they should, or if there is undue resistance to rotation of the propeller-shaft (grounding, or a foul hawser, are not unlikely causes) the engine may fail to start, and it is necessary to wait until the air supply is replenished before a further attempt is possible; with air starting this is

inevitable, although "cross-connecting," with adequate reserve storage, will minimise the trouble. An invaluable aid is the inter-connecting of the air-injection vessels of all the engines in the same compartment, since without injection air a Diesel engine cannot be started.

5. One of the most serious troubles is that which may arise from the introduction into the working cylinders of fuel before the proper time. In such a case the engine ceases to be a Diesel engine, and pre-ignites (mostly after misfiring, and therefore with the chances of a multiple charge), in which case combustion takes place not at constant pressure as desired, nor at constant volume as in ordinary types of internal-combustion engines, but in a volume which is being reduced during combustion. This means large increases of pressure, temperature and stress during combustion, which may result in violent knocking, overheating, and stressing of parts, and even in disaster. The most frequent cause of this trouble is that of stuck-up, sluggish, or inoperative fuel-valves, due either to bad alignment or to seizure in the glands. Improvements in design will minimise the risk. A further frequent cause of misfiring is the cooling of the power-cylinders, due to the rapid expansion of high-pressure starting air, the admission of which may be frequently repeated in cases of faulty starting, and the corresponding admissions of fuel to the cylinder may be overlooked, to cause disaster when ignition does occur. Another, but controllable, cause is the abuse of the process of "priming"—*i.e.*, filling the fuel-delivery pipes with fuel. So long as adequate precautions are taken the process is safe; but if, owing to a fuel-valve being open, or subsequently lifted off its seat, or by-pass valves being left shut up, fuel enters the cylinder and is allowed to lie on the piston-crown, accident may, and probably will, happen due to pre-ignition, as just described. Such results may be disastrous in large engines, even with relief-valves fitted to the combustion spaces.

6. Air-compressors have given, in the early stages of development, considerable trouble. The principal causes have been excessive lubrication, inadequate cooling during compression and between the stages, inefficient drainage, and insufficient reliefs. These difficulties have now been entirely surmounted, and the latest compressors run for months with only moderate attention. In certain makes of engine, compressors have been dispensed with for the injection of fuel, but it is an open question whether the advantages balance the disadvantages, especially if air is required for reversing the engines. The mechanical pulverisation of heavy fuel cannot be made so efficient as with air.

7. Air starting-valves will occasionally stick, and in such cases either starting air is wastefully admitted during the whole of the stroke, and is supercompressed in the cylinder, and/or hot products of combustion pass from the cylinder into the starting-pipe. Means should be provided for working the starting-valves when the engines are under way, to ensure freedom of motion and absence of leakage.

8. It may safely be said that after training no abnormal skill is necessary either to locate the cause of these troubles or to remedy them; it is a common-sense process mostly, but one feels that, as previously stated, full advantage should be taken of the "results of experience."

It will be noted that no complaint is made as to reversing. This difficult problem has been satisfactorily solved in both four and two-cycle engines. It is true that this is more easily effected in the latter case than in the former, but efficiently in both.

We now come to the possibilities of the future, based on previously ascertained facts, and here one walks, of necessity, on delicate ground. Nevertheless, it is hoped that the conclusions drawn will at least be logical, and certainly that they will not be exaggerated, for exaggeration is worse than misleading.

There is a limit of size below which Diesel engines cannot be made at all, and, further, a limit below which they cannot be made commercially. A factory was established at Munich to manufacture Diesel engines of 5 horse-power per cylinder on the four-stroke principle, running at 600 revolutions per minute. The engines were fairly successful, but the undertaking was not successful financially. Later, in 1911, an experimental single-cylinder engine, designed to develop 10 brake horse-power at 1000 revolutions per minute, and working on the two-stroke Diesel cycle, was constructed and tested satisfactorily; but it was not a commercial success, since its cost exceeded by far what would be regarded as a fair market price for an engine of the power. These cases, however, are not devoid of scientific interest, as showing that Diesel engines can be made in very small units and to operate at high speeds, although in such cases they are not marketable commodities on account of high prime cost.

Before dealing with other matters, it may be of interest to refer to two cases of engines installed in the same ship, one a four-cycle and the other a two-cycle Diesel engine, each running at the same speed (500 revolutions per minute), and occupying the same space. It was found that 85 brake horse-power was the limit possible with the four-cycle engine, and 125 brake horse-power that with the two-cycle engine; the weight of the engines in running order was as nearly equal as possible. The ratio of power for equal weight and space is therefore about 50 per cent. in favour of the two-cycle, which is rather surprising in units so small.

Turning now to the other extreme—the large units of power—a survey of the principles involved, from which deductions are to be drawn, may not be amiss. The results of forty years of experience with the reciprocating marine steam-engine have shown that piston speeds of from 750 ft. to 1000 ft. per minute are rarely exceeded, and even in the latest practice with high-speed reciprocating engines as were fitted in torpedo-boat destroyers, 1200 ft. per minute was regarded as a limit (18-in. stroke and 400 revolutions per minute). It is therefore reasonable to regard 1200 ft. per minute as the limit to be approached, but not exceeded, and 1000 ft. per minute as a reasonable limiting figure to deal with when considering the application of Diesel engines in high powers to purposes of marine propulsion. Already Diesel engines in ships are running at piston speeds varying from 750 ft. to 1000 ft. per minute, and in exceptional cases rather higher (1100 ft. per minute).

Regarding, therefore, 1000 ft. per minute as a standard of comparison, and assuming that the mean effective pressure in the cylinders is 100 lb. per sq. in. (which represents an average of current practice), and that due to reasons connected with dissipation of heat, the ratio of stroke to bore is unity as a minimum, preferably higher (take 1.2 for the sake of comparison), the following may be deduced when investigating or comparing types and designs. Any deviation from the basis figures assumed will, of course, make corresponding alterations in the proportions of the engine, but will not affect the general question.

Taking, first, the case of light, fast vessels of the destroyer type. Modern destroyers are almost invariably propelled by means of high-speed turbines, supplied with steam by water-tube boilers of large power per unit, and generally oil-fired. Speed being the great essential for such vessels, lightness and compactness of machinery is vital. Such steam-propelling machinery, with auxiliaries, will weigh from 27 lb. to 35 lb. per shaft horse-power. If, instead of such machinery, it is desired to instal Diesel engines, the following results:—1. They must be reciprocating engines, since the principle of the Diesel turbine is practically and theoretically impossible with our present knowledge, due principally to the fact that only a negligible portion of the products of combustion are condensable, and the great advantage of vacuum in turbines cannot therefore be realised. 2. They must run at high speed, and head-room will practically limit the type to single-acting engines. 3. Weight limitations will necessitate the adoption of the two-stroke cycle in preference to the four-stroke, and it may be necessary to provide for mean pressures greater than 100 lb. per sq. in. 4. There must be some substantial advantages to justify the change.

Now, the lightest Diesel engines made weigh (without auxiliaries) about 56 lb. per brake horse-power, and consume, say, ½ lb. of fuel per brake horse-power, whilst steam-turbine installations, complete with auxiliaries, weigh, as said before, about half as much per shaft horse-power, the consumption of oil-fuel being rather under 1 lb. per brake horse-power. The installations can only be comparable if the weight of machinery plus fuel for a given displacement, speed, and radius of action is approximately the same in both cases; and, even were that possible, the advantage would be with the steam machinery, owing to the more rapid lightening of the vessel due to the difference in fuel burnt and a corresponding augmentation in speed.

A case has been worked out in some detail, and shows that the proposal is impracticable for large torpedo-boat destroyers of high power and speed, since no saving in fuel can be made to compensate for the extra weight of the machinery in such vessels. Only when the power is comparatively small, and/or the weight of fuel carried considerably more than at present, is it possible to instal Diesel engines in torpedo craft to advantage even if at all.

The case of the light unarmoured cruiser is practically no better than that of destroyers, the only possibility being the installation of small Diesel engines for cruising, whose economy at cruising speeds might justify their installation, although they are of necessity dead weight to be uselessly carried about at full speed, unless very special arrangements are provided which would be both heavy and costly.

Considering now armoured vessels, such as large cruisers and battleships:—

1. *Large Cruisers.*—The speed and power of these vessels is necessarily high, of the order of 30 knots and 70,000 shaft horse-power. In such large reciprocating machinery the speed of rotation must be comparatively low, since, if the power per cylinder is to be high (*i.e.*, not too many cylinders fitted), the diameter of each cylinder must be large and the stroke no less (preferably more); hence low revolutions with limitations imposed by the piston speed. The power per cylinder and per shaft is limited by the capacity of means for manufacturing, by propeller requirements as regards efficiency, by conditions of available head-room and armour protection, apart from the great Diesel troubles which will certainly be experienced in very large units per cylinder.

Alternative cases have been worked out in considerable detail on the basis of equal powers per shaft for the development of 72,000 brake horse-power on 2, 3, 4, 6 or 8 shafts, with 6, 8, 12, 18 or 24 cylinders per shaft, the engines being two-cycle, double-acting. A few selected examples are contained in the table in the next column, the figures being in all cases estimates based on preceding assumptions and present knowledge. From this table, and taking it to be fairly accurate, it is apparent that the only reasonable solution is to adopt a moderate power per cylinder (say 750 to 1500 brake horse-power), a considerable number of cylinders per shaft, and a number of shafts—not less than four, preferably six or even eight. Under these latter conditions, Diesel engines for propelling battle-cruisers are possibilities, though their adoption is likely to be deferred for some years yet, permitting meanwhile a more gradual, and therefore a less artificial and more sturdy, growth from present sizes.

2. *Battleships.*—In these vessels, speed, although desirable, is not so vital as in cruisers, and the power is much less. A case worked out showed that, with an equal number of shafts as for steam machinery, equal powers and speeds with double-acting two-cycle engines can be obtained as with steam, on equal machinery weights, including auxiliaries in each case, whilst no increase in displacement is necessary, the fuel capacity need not be reduced, but the radius of action (including fuel for auxiliaries) can be increased at full speed at least three-fold, and at cruising speeds at least four times. Such a proposition is possible from an engineering point of view.

Number of Shafts ..	2.	3.	4.	6.	8.
Number of cylinders per shaft	6	8	12	12	12
B.H.P. per shaft ..	36,000	24,000	18,000	12,000	9,000
B.H.P. per cylinder ..	6,000	3,000	1,500	1,000	750
Total number of cylinders	12	24	48	72	96
Bore of cylinders in.	60	42½	30	24½	21½
Stroke .. .. in.	72	51	36	30	26
Revolutions per minute	85	120	170	200	230
Maximum load on piston . .. tons	630	315	158	106	8
Diameter of piston-rod .. .. in.	19	13½	9½	8	7
Diameter of each cross-head pin .. in.	26½	19	13½	10½	9¾
Length of each cross-head pin .. in.	26½	19	13½	10½	9¾
External diameter of crank-shaft .. in.	46	36½	29½	24	21
Internal diameter of crank-shaft .. in.	23	18½	14¾	12	10½
Axial length of crank-webs .. .. in.	39	30	23½	19	16
Length of crank-pins in.	61½	39	24	20	17½
Thickness of cylinders .. .. in.	6	4½	3	2½	2¼
Approximate over-all length of engine ft.	112	116	122	100	87
*Working height above crank-shaft .. ft.	42	30	21	18	15
*Engine projects above water-line .. ft.	23	11	2	−1	−4
Approximate total weight of main propelling machinery and its auxiliaries tons	6,500	6,000	5,250	5,000	4,750

* In a special design which is being evolved, these figures may be capable of a reduction of about 15 per cent.

3. *Submarines.*—An eminently suitable field for naval Diesel engines is the surface propulsion of submarine vessels, and it is to this purpose that this engine has been most widely applied. The powers required do not exceed those obtainable from reliable engines, the space can be provided to accommodate them, and weight is not prohibitive.

Hitherto head-room available has limited the application to the single-acting type, and it is extremely doubtful whether double-acting engines can ever be fitted, due to the same reason, unless the dimensions of submarines are largely increased.

Favourable installations can be made of Diesel engines for emergency lighting, dynamo, and auxiliary machinery driving in large vessels, and for the propulsion of tank vessels, fleet auxiliaries, and ordinary merchant vessels of moderate powers and speeds; but large merchant vessels and ocean liners fall more under the general conditions obtaining for battleships and large cruisers. Each such case, however, has to be considered on its merits and known conditions of service, so that it is not well to generalise, particularly in mercantile propositions.

If this paper has but had the effect of turning one's thoughts to what has been done and to what may be done in the future, it will have fulfilled the object of the author.

INDUSTRIAL WAR-TAX RESERVES IN GERMANY.—The question of war-profit taxation of the German industry is being very much discussed at present. The law for the taxation of war-profits ordains that limited companies, mining undertakings, &c., are bound to put 50 per cent. of the additional profits earned during a financial year in war-time aside as a special reserve. A number of industrial companies have, accordingly, in their annual balance-sheet made reserves for the war-profit tax. The reserves in question, however, are not by any means always visible, whilst other companies have invested the reserves in question in State bonds in such a way that they do not actually appear in the balance-sheet. A list of some fifty German companies which have published or decided upon their balance-sheets since the law came into operation in December, 1915, contains some interesting particulars as regards these reserves:—

	Marks.
Rhenish Metal-Ware and Machine Company	5,300,000
Hirsch Copper and Brass Works	4,000,000
Adler and Oppenheim Leather Company ..	3,000,000
Thale Iron Works	1,900,000
Rheydt Electrotechnical Company	1,850,000
Gasapparatus Company, Mannheim	1,800,000
Wiemann Leather Company	1,400,000
Neckar Ulmer Cycle, &c., Company	1,000,000
Wanderer Cycle Company	1,000,000
Dürkopp Cycle Company	1,000,000

The list also comprises several textile companies, spirit factories, &c. The aggregate war-profit tax reserves of the companies in the above list, which number fifty-three concerns, amount in the aggregate to 34,500,000 marks, or an average of 650,000 marks per company. There are altogether 6500 German limited companies, of which it is surmised that perhaps a thousand may be subject to war-profit taxation, but the average of the tax per company cannot be put at anything like the average of the reserves of the above fifty-three companies.

THEORY AND PRACTICE IN THE FILTRATION OF WATER.*

By WALTER CLEMENCE.

OPEN sand filters for purifying waters for potable purposes have now been in use for nearly a century, and since 1830 they have been continuously used in connection with the London water supply. The first sand filtration plant, designed by James Simpson for the Chelsea Water Company, consisted of decanting basins in which the raw water could be kept at rest for twelve hours, and open filter-basins in which a layer of fine sand, 2 ft. 6 in. deep, was placed on a bed of gravel of about the same thickness. In the gravel bed brick collecting-drains, with arched covers, were constructed. These large drains were found to induce a too rapid flow of the water through the sand immediately over them, and in later practice smaller drains were used, which were distributed over the whole area of the floor of the filter to secure an even speed through the bed.

During the last twenty years what is known as the "mechanical filter" has been introduced, in which the arrangement of the filtering materials differs little in section from that adopted in open sand-beds; but the water under treatment is passed through the materials at a speed from twenty to sixty times greater than that which has been found in practice to represent a safe limit of speed with slow sand filters, in order to obtain complete purification of the water. This limit is generally agreed to be from 50 to 75 gallons per sq. ft. per twenty-four hours, and it is obvious that, if the process of purification is found to be incomplete in the slow filter on exceeding this speed, it must be much more so in the rapid filter.

With filters of fine sand working at slow speed it is found that practically all matters in suspension in the water, whether living organisms (other than bacteria) or silt particles, are retained on the surface of the filtering medium, where they eventually form an impervious layer, and it becomes necessary to remove this in order to restore the permeability of the bed. This has long been recognised as one of the greatest drawbacks to slow sand filtration, yet the theory became established that the efficiency of the filter as an agent for the purification of water depended almost entirely on the layer of slimy mud which has been observed to form on the surface of the filter after it has been brought into use. Many articles have been published giving details of the various matters of which this layer has been found on examination to be composed, and in some cases it has been claimed that the presence of specific plants or other organisms in the layer has an effect, detrimental or otherwise, on the action of the filter. But while it is frequently pointed out that this film retains some 98 per cent. of the bacteria found in the raw water, the important fact that the majority of these bacteria are nitrifying organisms, and the most active agents in the organic purification of the water, is too frequently overlooked.

It has been established in practice that, with filters *on which a filtering layer is allowed to form* (the italicised words are important), the efficiency of the filter is impaired if the layer is disturbed, and that after its complete removal when a filter is cleaned, the chemical and bacterial efficiency of the filter is not restored until a film has again formed. But the formation of the film is attended with a practical disadvantage in the working of the filter, as it is accompanied by a constant increase in the "loss of head" or pressure required to force the water through the filter, so that by the time the filter is in a condition to yield a water of sufficient purity for potable purposes, the output has been considerably reduced, and constantly decreases until it becomes necessary to remove the "filtering film," when the process of ripening and working with constantly diminishing output must be repeated. These are the conditions under which sand filters were worked for a period of seventy years, and in a large number of cases the conditions are the same to-day.

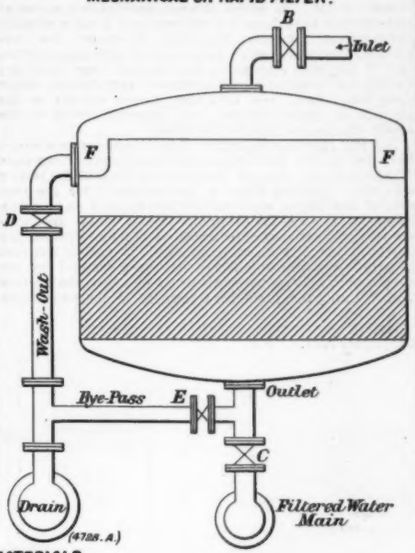
The chief disadvantages of sand filtration under such conditions are:—

1. Owing to the time occupied in cleaning and ripening each filter, and the limited time during which it can be worked at its maximum rate of delivery, it is necessary to provide a much larger total filtering surface than would be necessary if the filters could be worked at something approaching their maximum rated speed for prolonged periods.

2. The labour required for cleaning the filters, and removing, washing and replacing sand, is considerable.

3. There is a constant waste of water (which in the majority of cases has to be pumped from a lower level) whenever a filter is emptied for cleaning, or when the effluent is run to waste during the process of ripening a filter and also for washing sand, an operation which must always be carried out with filtered water.

Fig. 1. GENERAL ARRANGEMENT OF A MECHANICAL OR RAPID FILTER.

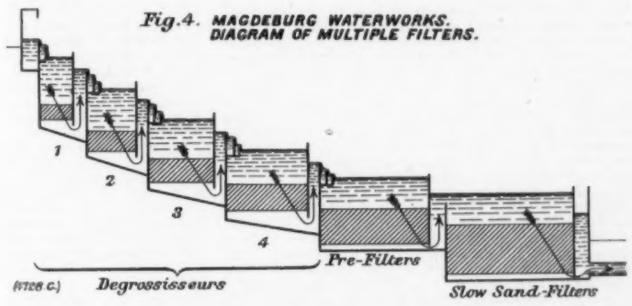


ARRANGEMENT OF FILTERING MATERIALS.

Fig. 2. IN AN ORDINARY SLOW SAND-FILTER.

Fig. 3. IN MULTIPLE FILTRATION.

Fig. 4. MAGDEBURG WATERWORKS. DIAGRAM OF MULTIPLE FILTERS.



Much attention has been paid by engineers in recent years to the improvement in the conditions of working and in the design of filters. The interest aroused in connection with this subject has resulted in the formation of two distinct methods of practice based on widely divergent theories. On the one hand, those who support the theory that the bacterial purification of water by filtration is chiefly due to the mechanical action of straining have developed the mechanical filter, in which a film is created artificially by the use of a coagulant, and a high speed is adopted. On the other hand, Armand Puech proved by experiment and observation that the formation of a film on the surface of a filter was a hindrance rather than an aid to purification, and Puech and Chabal have developed the system of multiple filtration which is founded on the now ascertained fact that the formation of a film, either natural or artificial, on the surface of the filtering medium is unnecessary and undesirable. In the system of multiple filtration the slow sand filter is retained, but the water is previously clarified by passing through successive layers of gravel and sand. During this preliminary treatment all solid matters in suspension are eliminated, together with the spores of algæ, so that no film can form on the surface of the final filter. As the nitrifying bacteria are not retained on the surface of the sand, they penetrate into the filter itself to a considerable depth, so that the bed becomes an active agent of purification, and not merely a support for the filtering layer of limited efficiency on its surface. Yet it is found that slow sand filters, which form the final elements in a system of multiple filtration, will, without the formation of a film, give far better results, chemically and bacteriologically, than filters on which a film is allowed to form.

MECHANICAL FILTERS.

Although there are many types of filters, for each of which special advantages are claimed, the diagram, Fig. 1, shows the essential features common to all mechanical filters. The filtering surface varies from 50 sq. ft. to 230 sq. ft. in each unit, and the speed of working is modified according to the water to be treated, but is rarely less than 8 ft. 6 in. vertical fall per hour, and is sometimes as much as 50 ft. From ten to twenty minutes appears to be the usual time allowed for the passage of the water from inlet to outlet. When the filters are open at the top, and depend on gravity for their working head, it is rarely possible to obtain a speed of more than 20 ft. vertical fall per hour, and at that speed the filters require cleaning frequently, as it is impossible to maintain the necessary working head which constantly increases as the filtering medium becomes foul.

For high rates of filtration, from 20 ft. to 50 ft. vertical fall per hour, the head is induced or the filters are closed in so that they may be put under pressure from the inlet main. Each unit is controlled by four valves, lettered B, C, D and E on the diagram, and when the filter is in use D and E are closed. Raw water is admitted at B, and after passing vertically downwards through the filter is carried to the collecting-main through the outlet pipe controlled by the valve C. In order to clean the filter, the valve D on the wash-out pipe is opened and the inlet valve B is closed. In the case of filters of the enclosed or pressure type, this is sufficient to cause a reversal of the flow, as the filtered water main is under pressure from other units of the battery, and the water flows upwards through the filtering medium into the collecting channel F and thence to the drain through the wash-out valve D.

With filters of the open or gravity type, the outlet valve C is closed as well as the inlet, and an auxiliary valve on a pipe connected to the space below the filtering medium is opened to admit filtered water from the supply mains, if these are under sufficient pressure, or from an auxiliary pump. When the filtering medium is sufficiently clean, the valve D is closed, and it is then usual to start the filter and run the filtrate to waste for a time by closing the main outlet valve C and opening an auxiliary outlet valve E connected to the drain.

Another feature common to all mechanical filters is the provision of means for breaking up and agitating the filtering medium during the process of cleaning. This is accomplished either by the use of mechanical rakes or stirrers buried in the medium, which may be revolved by gearing, or by the use of steam or compressed air which is admitted at the bottom of the filter with the wash-water. Owing to the high speed employed, there would be little or no reduction in the number of bacteria without the formation of an artificial film. Sulphate of alumina is generally used as a coagulant, and in the case of soft waters lime must be added; by this means a gelatinous film is formed on the filtering medium. The apparatus used to mix and add the chemicals employed is very similar to that used in water-softening installations, and generally consists of a combination of measuring-weir and tipper with float controls. It will be seen therefore:—

1. That the practice of mechanical filtration is based on the theory that a filtering film is essential.

2. That the speed of the filters is always high, so that the length of time during which the water is under treatment is not considered of importance.

3. That when cleaning, the filtering materials are violently agitated throughout their mass.

4. That the bacteriological purification of the water is dependent on a single operation carried out with extreme rapidity, and that the sole line of defence against the passage of pathogenic organisms through the filter consists of an artificial gelatinous film.

MULTIPLE FILTRATION.

The theories which have led to the development of multiple filtration are directly opposed to those which have been considered in connection with mechanical filtration. It is now an accepted fact that the reduction of organic matters in solution in water, and their resolution into mineral matters or nitrates, is due to the action of bacteria, and it is believed that the vast majority of microbes found in organically impure waters belong to the class of nitro-bacteria first discovered by Winogradsky. The nitro-bacteria are said to consist of several species having different characteristics, but all are aerobic—that is, they thrive only in the presence of free oxygen. They exist in water and appear to thrive and form colonies in soil or sand, but they are not found in soil at a depth of more than a few feet from the surface. Careful experiments by Reinsch and others have shown that in ordinary sand filters having a depth of about 3 ft. of sand, the number of bacteria found in samples of water drawn at various depths in the sand-bed is gradually reduced from top to bottom, the number varying with the speed at which the water is passed through the bed.

The author has observed that in slow sand filters forming the final elements in a system of multiple filtration, a section of the sand in a filter which has been at work for some months shows a brown stain extending downwards through the bed. This stain decreases in shade from the surface downwards and appears to be due to the presence of innumerable colonies of nitro-

* Paper read before the Institution of Mechanical Engineers on April 14, 1916.

bacteria, which coat the grains of sand to a considerable depth instead of being retained in the "filtering-layer" on the surface of the sand, as in the filters which are fed with water which has not been previously clarified.

It is found in multiple filtration that the slow sand filters will yield good results if put to work again at their maximum speed after scraping, provided the sand has not been allowed to become dry. This is shown by a reference to the diagram, Fig. 10 [to be reproduced in a later issue], showing the working of the Cawnpore filters during 1913. Filter No. 5 was scraped on June 15, and was again brought into use on June 16 with a delivery of 1,200,000 gallons (the area of the filter being 20,000 sq. ft., which equals 60 gallons per sq. ft. per 24 hours). This filter was worked until the end of June at speeds varying from 55 to 67 gallons per sq. ft. per 24 hours. The number of bacteria in the effluent on June 16 was 44 per cub. cm., and on ten other occasions between June 17 and the end of the month the figures were 28, 14, 28, 8, 22, 20, 20, 14, 16, and 12.* After re-sanding a filter the results are for a short time less perfect than with sand which has been in use for some time. They are still, however, sufficiently satisfactory to permit the water to be used if the filter is run for a short time at a slow speed.

These facts were carefully considered in the development of the system of multiple filtration. It was seen that the filtering-film, composed in the main of a felted mass of algæ, fine silt particles, and debris of all kinds, owed its limited efficiency as an agent in the purification of water to the presence of nitrifying bacteria in the film, but that the algæ and other materials were in themselves detrimental to the efficiency of the filter, as it was impossible to remove the layer of silt, &c., from the surface of the sand without at the same time removing the principal agent of chemical and bacteriological purification. The efficiency of the filter is found to be greatly increased if the nitrifying organisms are allowed to spread through the whole mass of the filtering materials and their vitality maintained by a constant supply of oxygen. Formerly the formation of the film prevented this, and the fact that the filter became inefficient after scraping indicated that the sand itself had no influence on the chemical and bacteriological character of the water.

The first problem to be considered is how to prevent the blocking of the filter by the accumulation on its surface of the matters in suspension in the water, while at the same time allowing the nitrifying bacteria to gain free access to the filtering materials. When this is accomplished, the colonies of nitrifying bacteria form a slimy layer on the sand grains in the upper part of the bed, and gradually spread downwards until the filter is in a condition to deal actively with the organic matters in solution during the passage of the water through the sand, so that as the thickness of the layer containing the purifying organisms increases, so the speed of the filter can be increased with perfect safety, for the really effective agent of purification is now spread through a considerable depth of the mass of sand instead of being limited to a thin film on the surface. It is found in practice that the formation of this natural bacterial slime in the filter has very little effect in restricting the passage of the water through the sand.

If the action of a sand filter is chiefly confined to a "filtering film" on the surface of the sand, represented by the thick black line in Fig. 2, it may be argued with some reason that little work is done by the filtering materials themselves, except that they form a convenient support for the film, and while there are obvious practical reasons for the disposition of the layers of gravel and sand shown by the diagram, the theory under consideration requires that the arrangement should be reversed and the water passed through the layers of coarser materials first.

To reverse the disposition of the filtering layers in an ordinary sand filter, even if it were practicable, would necessitate the employment of the same speed of filtration in each layer, and it is found in practice that if very turbid water is passed at a slow speed through a layer of coarse gravel, the surface will become blocked with mud in a comparatively short time, and that a layer of pebbles forms a more efficient strainer if the speed of the water is so regulated that a coating of mud may be left on every pebble in the mass. These considerations require that various layers of pebbles and sand shall be placed in separate basins and disposed according to their grading from coarse to fine in successive stages as in Fig. 3.

Nitro-bacteria in water are active in destroying organic matter at all times, and a certain reduction in organic matter takes place even during the comparatively rapid passage of the water through the degrossisseurs, as the first elements in a system of multiple filtration are called, so that the total time during which a water is under treatment, from the raw water inlet to the outlet from the final filters, must be carefully considered in the design of an installation. Reduction in the number of bacteria proceeds also with the reduction in organic matter, and the water is reduced to a condition of comparative safety before reaching the final filters. It appears probable that pathogenic organisms disappear in the process of multiple filtration, not because they are retained by the mechanical process of straining, but because water from which organic matters in suspension and solution have been entirely removed is not a suitable environment for their continued existence. Such organisms thrive in organic matter and a high temperature, and it appears reasonable to suppose that they are devitalised in water at a temperature considerably lower than blood heat, and that they perish rapidly in the absence of organic matter, and possibly owing to the action of nitro-bacteria in the filters.

Having enumerated some of the considerations which have led to the development of the system of multiple filtration in its present form, it may be said the theory that the "filtering film" is not necessary for the successful working of slow sand filters appears to be established by the results of practice; and while first consideration must always be given to details affecting the purity of the filtrate, an enormous reduction in the cost of working of multiple-filters has been secured by the adoption of mechanical methods of cleaning the various units forming the plant for treatment of the water antecedent to filtration, while the absence of a film on the final slow sand filters, and the fact that these are now supplied with a physically clear water, renders unnecessary the expensive operation of scraping except at very rare intervals.

The first large installation of multiple filters for a potable water supply was constructed by the authorities of the City of Paris at Ivry, in 1900, at a time when sand filters were first used in France on a large scale. The sand filters are twenty-seven in number, with a total area of 230,000 sq. ft., and they are supplied with water strained in four successive stages in sixteen degrossisseurs or strainers, with a total area of 47,500 sq. ft. The strainers are supplied with filtering layers of pebbles only, and the suspended impurities in the raw water, which is drawn from the Seine, are removed to such an extent that the sand filters run on an average for three months. A similar plant was constructed about two years later at the Sunbury Works of the Metropolitan Water Board for dealing with 10,000,000 gallons per twenty-four hours. In these installations no provision is made for aeration of the water or for cleaning the degrossisseurs by mechanical means, and although the results show a great improvement in all respects over ordinary sand filtration combined with decantation, they are not to be compared with the results obtained in more modern installations.

As the system has progressed, three notable features have been introduced:—

1. It is now the practice to introduce a pre-filter of coarse sand between the degrossisseurs and final filters. This has the effect of almost completely eliminating suspended matters, and greatly prolongs the life of the final filters.

2. For potable waters cascades are introduced between the successive stages of training, so that the supply of dissolved oxygen is fully maintained.

3. The degrossisseurs are fitted with an apparatus for rapidly removing the silt collected by the straining materials, by means of air and flushing with unfiltered water. The pre-filters are also frequently fitted with an apparatus for cleaning the surface of the sand while the basins are submerged.

The diagrams, Fig. 4, page 391, and Figs. 5 and 6, above, show the arrangement of some modern installations which it is proposed to describe, giving in each case particulars of the raw water and showing how the principle of multiple filtration has been adapted to suit local requirements, for, as no two waters present the same characteristics, it is essential that these should be studied carefully in the design of any installation intended to effect purification.

The four examples of multiple-filtration installations [1. *Magdeburg.*—River Elbe, a water usually turbid and polluted with refuse from factories. 2. *Derwent Valley.*—An upland water charged with peaty acids. 3. *Accra, Gold Coast Colony.*—River Densu, a water polluted with decaying vegetation from swamps. 4. *Cawnpore.*—River Ganges, a water organically pure, but usually turbid with clay and silt particles] hereafter described have been designed to deal with waters differing widely in character. In each case the slow sand filter is relied on for final purification, the rest of the plant being designed to bring the water to such a condition before reaching the final filters that the best possible results may be obtained from these. It will be noted that the arrangement of the degrossisseurs and pre-filters is varied in each case, according to the character of the water and the nature of the difficulties to be encountered in working the final filters.

1. MAGDEBURG (Fig. 4).

The source of supply is the River Elbe, which is usually turbid and polluted with the refuse from factories, &c., the quantity of organic matter being largely increased in the winter months by refuse from beet-sugar refineries. The plant* has a capacity of 9,900,000 gallons per 24 hours, and consists of four series of degrossisseurs or strainers, with cascades between each series, pre-filters of coarse sand, and slow sand filters. The latter have been in existence for many years, and are covered with brick arches, on which a layer of 3 ft. of soil is placed.

Formerly these filters were supplied with water previously passed through decanting basins, but as these proved ineffective, they were transformed into simple roughing filters. These were designed for too high a speed, and the filtering layer was unnecessarily thick, so that, as the whole mass of filtering materials became foul after some months' working, it was exceedingly difficult to clean them. They were therefore reconstructed, and the whole installation transformed into a multiple-filtration plant by the addition of degrossisseurs.

The degrossisseurs are in four series and 32 units, with a total filtering surface of 22,900 sq. ft., while the total area of the pre-filters is 43,000 sq. ft., and of the final sand filters 193,700 sq. ft. The speed adopted is as follows:—

	Vertical Speed in Feet per Hour.
Degrossisseurs 1	38.38
,, 2	21.94
,, 3	11.98
,, 4	5.22
Pre-filters	1.53
Sand filters	0.34

The effect of the simple device of cascading the water between the various stages is shown as follows:—

Dissolved Oxygen in Cubic Centimetres per Litre.	
Raw water of the Elbe	6.27
Loss after passing degrossisseurs 1, 2, 3	0.58
	5.69
Gain by cascade	0.55
	6.24
Loss on passing degrossisseurs series 4	0.71
	5.53
Gain by cascade	1.02
	6.55 =

saturation in dissolved oxygen at time of test, with temperature 18.5 deg. Cent. (65 deg. Fahr.).

The bacteriological results obtained from the multiple filters at Magdeburg have been remarkably regular. A table showing the results of 454 analyses, made during the month of November, 1910, was published in ENGINEERING, January 13, 1911. A summary of the results gives the following figures:—

—	No. of Samples Examined.	Bacteria per cub. cm.			Bacterial Purification.
		Highest	Lowest	Average	Per Cent.
Raw water	30	144,000	4,200	43,523	—
After degrossisseurs	30	10,000	1,500	3,771	91.33
After pre-filters	30	1,900	190	636	98.51
Sand filters	336	18	1	5.65	99.987
Collecting-well	30	14	3	7.4	—
Service reservoir	5	17	6	11.6	—
Town mains	3	14	4	8.0	—

Fig. 5. DERWENT VALLEY WATER BOARD. DIAGRAM OF MULTIPLE FILTERS, BAMFORD.

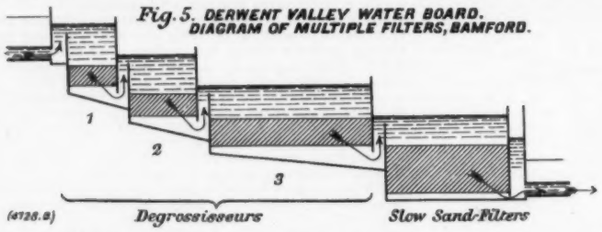
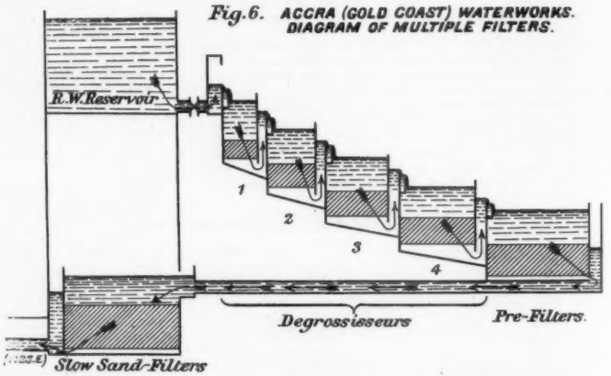


Fig. 6. ACCRA (GOLD COAST) WATERWORKS. DIAGRAM OF MULTIPLE FILTERS.



* Report by Captain C. L. Dunn, I.M.S., on the working of the Pucoh-Chabal Multiple Filtration Installation at Cawnpore, Table I.—Allahabad Government Press, 1913.

* ENGINEERING, January 28 and February 4 and 11, 1910.

The figure for albuminoid ammonia is reduced from 50 to 80 per cent., according to the season, while the free ammonia is always entirely eliminated, showing a reduction in organic matter in solution which is due to the length of time allowed for nitrification and the arrangements made for maintaining a supply of free oxygen during the process of purification.

The character of the raw water of the Elbe varies considerably, as may be seen from the following analyses made during the summer meeting:—

Analysis in Milligrammes per Litre.	July 5, 1907.	May 2, 1908.
Total solids	783.3	395.8
Loss on ignition	81.7	53
Sodium oxide (Na_2O) ...	235.1	105.2
Potassium oxide (K_2O) ...	13.4	2 8
Lime (CaO)	92.4	55.1
Magnesia (MgO)	32.1	20 3
Oxide of iron (Fe_2O_3) ...	0.3	0.3
Alumina (Al_2O_3)	1.1	1.7
Chlorine	287.0	133.0
Sulphuric anhydride ...	79.7	46.2
Silica	7.2	5.7
Carbonic anhydride ...	60.0	37.7
Nitrogen as nitrates ...	11.7	7.7
Nitrites	Traces	Traces
Free ammonia	0.04	0.06
Albuminoid ammonia ...	0.22	0.15
Oxygen consumed	7.60	5.4
Dissolved oxygen, cub. cm. per litre	5.62	7.5
Total hardness ... deg.	13.73	8 4
Permanent hardness ,,	7.85	4 3

The work accomplished in a given period by any filter, slow or rapid, is best understood by a statement as to the number of cubic feet of water which have passed through each square foot of filter area, or, in other words, the height of a column of water which has passed through the filter. Results stated in this way are easily comparable whatever the area or speed of the filter. The physical effect of multiple filtration on the life of the final or slow sand filters of the system is well illustrated by the following particulars relating to one of the Magdeburg filters. When supplied with water from settling-tanks, this filter required cleaning on thirteen occasions in six months, the average height of a column of water passed between scrapings being 54.79 ft. On each occasion the filter was worked to its maximum "loss of head" of 39 in. When supplied with water previously passed through the degrossisseurs and pre-filters, the height of a column passed through the same filter was 1022 ft., with a loss of head of 3 in. only. It has been already shown that in multiple filtration it is possible to start a sand filter, immediately after scraping, at its maximum speed without running the water to waste, and that good results are at once obtained.

This is borne out by the tables of bacteriological results already quoted, and appears to support the theory that a sand-bed, if left undisturbed, and through which water is allowed to pass continuously, becomes charged with nitrifying bacteria which have a most important effect in bringing about complete purification.

2. Derwent Valley Water Board (Fig. 5).

The large installation at Bamford, Derbyshire, deals with water from the impounding reservoirs at Derwent and Howden. The installation has a capacity of 72,000,000 gallons per 24 hours for the supply to Nottingham, Leicester, and Derby. The plant consists of three series of degrossisseurs divided into sixteen compartments, any one of which may be isolated for cleaning without interrupting the working of the remainder. There are no pre-filters, and the water passes direct from the degrossisseurs to the slow sand filters.

The degrossisseurs are fitted with an apparatus for cleaning the gravel by means of air, and the amount of labour required for working the installation is very small. The sand filters have a total filtering surface of 189,000 sq. ft., and the degrossisseurs 28,200 sq. ft. The speed adopted is as follows:—

	Vertical Speed in Feet per Hour.
Degrossisseurs, Series 1	21.62
,, Series 2	15.04
,, Series 3	5.75
Sand filters	0.5

There is usually a large amount of acidity in the raw water, due to the peat in the drainage area, and it is found that the acid increases after heavy rains. The degrossisseurs, series 1 and 2, contain crushed limestone as the filtering medium, which has been found to effect complete neutralisation of the peaty acids in the water. In the third series the filtering medium is screened calc-spar, and Leighton Buzzard sand is used in the final filters. The filters were first brought into use in 1912, and the following figures have been obtained as a result of the working of the installation in 1913 and 1914.

Test to Ascertain the Effect of the Degrossisseurs on the Period between Scrapings of Sand Filters: Bamford Filters, Derwent Valley Water Board.

Water that had previously passed through the degrossisseurs was supplied to sand filter No. 7. The filter was scraped on September 15, 1914, and it again required scraping on November 10, 1914. Length of run, 56 days. Area of filter, 27,000 sq. in. Quantity of water filtered, 67,512,000 gallons; average, 1,360,000 gallons per 24 hours. Average speed, 0.298 ft. per hour. Height of column passed between scrapings, 400.71 ft.

Sand filter No. 2 was also supplied with water from the degrossisseurs during the same season, and worked for 57 days between scrapings. The quantity of water filtered was 83,774,000 gallons, an average of 1,470,000 gallons per 24 hours, or 0.363 ft. vertical fall per hour. The height of the column passed between scrapings was 497 ft.

No. 1 filter was scraped on September 18, 1914, and was supplied with raw water. It required scraping four times during the period ended November 16, 1914. During this period the filter was actually in use on 51 days. The total quantity filtered was 59,309,000 gallons, or 1,163,000 gallons per 24 hours. The average quantity filtered between scrapings was 14,827,000 gallons. The average speed, 0.287 ft. vertical fall per hour. Height of column passed between scrapings, 88 ft.

In order to obtain an exact comparison, all the filters were stopped for scraping when the maximum loss of head of 3 ft. 6 in. had been reached. Although in this particular installation the system of multiple filtration has only been partially adopted, it will be seen that the result of preliminary straining through three successive layers of gravel is to increase the life of the final filters between scrapings from 4½ to nearly 6 times, with a resulting great saving in labour.

The following table shows the acidity in the raw water in a number of samples taken from the inlet to the degrossisseurs:—

1914.	Acidity in Terms of cm.³ of $\frac{N}{10}$ Solution of Sodium Carbonate Required to Neutralise 100 cub. cm. of the Water. cub. cm.
July 30	0.23
August 6	0.25
August 13...	0.35
August 20...	0.27
August 27	0.25
September 3	0.25
September 10	0.27
September 17	0.35
September 24	0.22
October 1	0.24
October 8	0.25
October 15	0.25
October 22	0.25

The raw water has always been acid, except for the period from July 24, 1913, to September 11, 1913, when the reaction of the weekly samples was neutral. This period was the close of the long drought of that dry summer. The effect of passing the water through the limestone in the first two series of degrossisseurs is to neutralise the acid completely, and to reduce to a safe figure the lead-dissolving power of the water. The hardness is naturally slightly increased.

The results of a test made on January 1, 1913, were as shown in the table below.

The working expenses in connection with the multiple filtration plant at Bamford have been found to be exceedingly low, and for the year 1913 amounted to 4s. 6d. per million gallons, or 0.054d. per 1000 gallons. This figure, of course, includes the cleaning of the degrossisseurs, with maintenance of the oil-engine and blower used in cleaning, scraping of sand filters, &c. The late Mr. W. B. Bryan gave the cost of working ordinary sand filters at the works of the Metropolitan Water Board as ¼d. per 1000 gallons, or about 5s. 11d. per million gallons.*

The filters at Bamford are constructed in concrete and brickwork throughout, with the exception of the apparatus for cleaning the degrossisseurs by air. This part of the work is in ferro-concrete.

Results of Tests of Samples of Water from Bamford Filters at Different Stages of Filtration: Derwent Valley Water Board.

Description of Sample. January 1, 1913.	Acidity in Terms of cm.³ of $\frac{N}{10}$ Solution of Sodium Carbonate Required to Neutralise 100 cm.³ of the Sample of Water.	Hardness in Degrees on Clark's Scale.	Amount of Lead Dissolved after 24 Hours in Lead Pipe of 1 deg. = 1 Grain of Lead per Gallon of Water.
		deg.	deg.
Sample of water from inlet to degrossisseurs	0.26	2.0	33.0
Sample of water after passing degrossisseur No. 1, containing coarse limestone ..	0.17	2.3	31 5
Sample of water after passing degrossisseurs 1 and 2, No. 2 containing medium grade limestone	Neutral	2.75	6.3
Sample of water after passing degrossisseurs 1, 2, and 3, No. 3 containing fine crushed calcium spar	Neutral	2.9	6.3
Sample of water after passing 3 degrossisseurs and sand filters	Neutral	2.9	6.6

The annual capital charges on the installation, calculated at 12,000,000 gallons per twenty-four hours, or 4,380,000,000 gallons per annum, are 1*l.* 8s. 2d. per million gallons = 0.338d. per 1000 gallons. The total amount of crushed limestone used as the filtering and acid neutralising medium in degrossisseurs 1 and 2 is 506 cub. yards. This material can be obtained locally at 6s. 6d. per cub. yard, but the actual cost of the material under the contract was 9s. per cub. yard, placed in the filters, or 227*l.* 14s.

Careful note has been taken of the action of the acid water on the limestone, and after passing 9000 million gallons of water through the filters, the total loss was found to be 300 cub. yards, costing, at 9s. per yard, 135*l.* = 3.6d. per million gallons, or 0.0036d. per 1000 gallons. A certain amount of this loss is, no doubt, due to attrition during the process of cleaning the gravel by air; but, on the other hand, this simple method of cleaning effectively removes all deposit from every particle of the filtering medium, leaving the maximum surface of limestone exposed to the action of the acid water.

It is found that the water takes up just sufficient calcium carbonate to neutralise the acidity, so that the method is both safe and economical, as, if the alkali were measured and added, it might sometimes occur that too little was added, and sometimes too much. Under the system adopted at Derwent Valley, the whole process is automatic and the cost exceedingly low, as no expensive apparatus has to be provided to add the lime. The cost of filtration at Derwent Valley is therefore 0.396d. per 1000 gallons, including working expenses, interest on sinking fund, and all outgoings.

Some notes on the use of sulphate of alumina with these filters, for the purpose of removing colour, are given in Appendix I.

3. Accra, Gold Coast Colony (Fig. 6).

This installation, although dealing with only 500,000 gallons per twenty-four hours, is very complete, and provides for treatment of the water in six successive stages.* The source of supply is the small River Densu, which is much contaminated with water from swamps full of decaying vegetation. As a result of a series of analyses of the raw water, Mr. Bertram Blount estimated that the maximum organic impurity might be represented by the following figures:—

Oxygen consumed (4 hours at 80 deg. Fahr.)	1.00 part per 100,000
Albuminoid ammonia	0.05 ,, ,,

It is hoped to reduce these figures within safe limits by aeration and slow filtration without the use of chemicals. The whole of the installation is constructed of ferro-concrete, and consists of four degrossisseurs in series and sets of five pre-filters and six slow sand filters. A raw-water reservoir holding twenty-four hours' supply is placed over the sand filters, the floor of the reservoir being slightly higher than the inlet to the filtration plant. The reservoir is of the same area as the sand filters, and is carried on ferro-concrete columns. The spaces between the outer columns are filled in with ferro-concrete panels, so that light is excluded from the final filters. The pre-filters, and also the degrossisseurs, are fitted with apparatus for cleaning by air, which is supplied from an electrically-driven blower. One native "boy" easily controls the plant. The combined filtering area of the degrossisseurs and pre-filters is 4870 sq. ft., and of the sand filters 12,200 sq. ft. A slow speed has been adopted throughout, as will be seen from the figures given below.

As the installation has only been working for a short time, it has not yet been possible to work it at its full capacity, but some notes on results recently obtained from a partial trial of the installation are given in Appendix II.

	Vertical Speed per Hour. Ft.
Degrossisseurs 1	11.91
,, 2	7.91
,, 3	5.95
,, 4	3.95
Pre-filters	1.18
Sand filters	0.27

(*To be continued.*)

Malay Peninsular Trade.—Statistics to hand from the Straits Settlements reveal, says the *London and China Telegraph*, a remarkable recovery of trade during the past year. With large increases in the price of rubber and tin, the two principal products of the Malay Peninsula, this recovery, perhaps, was to be expected; but the most satisfactory feature to be noticed is that not only have the figures for 1914 been eclipsed, but there is actually a substantial increase when comparison is made with 1913. For the three years the statistics were:—

	Imports. £	Exports. £	Total. £
1913	55,483,818	44,999,998	100,483,716
1914	46,121,866	39,944,540	86,066,406
1915	52,480,270	50,674,414	103,154,684

It will be seen that, whereas there was a shrinkage of 14,417,310*l.* in 1914, owing largely to the war influence in the latter half of the year, there is actually an increase in 1915 of 2,670,968*l.* over the excellent figures of 1913, and of 17,088,278*l.* over 1914. The increase in imports amounted to 6,358,404*l.*, and in exports to 10,729,874*l.* The value of tin exported was 10.694 344*l.*, of Pará rubber 10,606,599*l.*, and of copra 1,410,181*l.* Imported manufactured articles were valued at 8,794,809*l.* last year, as compared with 8,289,667*l.*, rising last year from 1,835,141*l.* in the first quarter to 2,515,049*l.* in the last quarter.

* Proceedings of the Institution of Mechanical Engineers, 1909, page 107.

* See Engineering, November 5, 1915.

THE PHYSICAL SOCIETY OF LONDON.

AT the meeting held on March 24, 1916, at the Imperial College of Science, Mr. F. E. Smith, A.R.C.S., Vice-President, in the chair, a paper entitled "*A New Method of Determining Ionic Velocities*" was read by Mrs. C. H. Griffiths, B.Sc.

In the experiments described the cathode, which consists of a horizontal copper disc perforated with two holes, is mounted in a cylindrical glass tube open at the lower end. The whole is suspended from the beam of a balance, and is immersed in a vessel of copper sulphate. The anode is a copper spiral fixed in the electrolyte some distance below the mouth of the cathode vessel. From the rate of change of weight of the suspended system during the passage of a current the ionic velocities can be determined.

Discussion.—Dr. S. W. J. Smith discussed the paper at some length. At his suggestion his remarks are omitted in order to save space. They will appear in the Proceedings.

Mr. F. E. Smith admired the manner in which small difficulties had been overcome. Some years ago he had determined the electrochemical equivalent of silver with the anode suspended from the beam of a balance. If Mrs. Griffiths intended continuing these experiments, he would suggest the use of such salts as silver nitrate rather than copper sulphate.

Mr. J. H. Shaxby communicated the following remarks: It may be noted that the use of a relation, implicit in the reasoning but not actually employed, leads to a simple formula for calculating V without the necessity of separate determinations of m_1 and m_2. This saves a rather lengthy calculation, and incidentally avoids the necessity for relying on data in Landolt obtained by other workers. The relation is that the current $N\epsilon\,(U+V)$ is also equal to $m_1 q\,(U+V)$. (In fact, from the values given, $N\epsilon = 34.36$ and $m_1 q = 34.12$.) If, then, we substitute $\frac{e}{m_1 q} - V$ for U in the equation

$$m_2 V - m_1 U - n\delta\rho V + \frac{e\rho}{qd} = W$$

(loss in weight observed),

we have

$$m_2 V - m\left(\frac{e}{m_1 q} - V\right) - n\delta\rho V + \frac{e\rho}{qd} = W,$$

or

$$V(m_1 + m_2 - n\delta\rho) = W + \frac{e}{q} - \frac{e\rho}{qd};$$

i.e.,

$$V n(1 - \delta\rho) = W + \frac{e}{q}\left(1 - \frac{\rho}{d}\right).$$

The quantity δ is derived from the statement that "total mass of salt in cathode vessels diminishes at the rate of $(m_1 + m_2)\,A\,v$ gms./sec." Now this diminution is not by the elimination of salt *qua* salt, but in the form of already dissociated ions. The calculation of δ, from the variation of density of a solution with concentration, lumps together undissociated and dissociated salt. If we may suppose the ions to be of great density, the value of δ would be very small. If we neglect δ and re-calculate V, we find for experiments (12), (9), (3), and (6) respectively the values 6.339, 3.138, 4.011, and 1.561 ($\times 10^{-4}$), leading to the values for $\frac{v}{u+v}$ 0,6584, 0.6561, 0.6627, and 0.6634. For the lowest concentrations these agree with other workers' figures. Metelka's results for densities 1.019 and 1.038 suggest similarly constant values of $\frac{v}{u+v}$ for various concentrations, and are also in good agreement with Mrs. Griffiths's figures (as thus re-calculated).

Dr. Griffiths, replying on behalf of Mrs. Griffiths, expressed thanks for the interest taken in the paper by Dr. Smith and for his rational criticism. He agreed that further research was advisable on the density of electrolytically deposited copper, and thought that Mrs. Griffiths might be able to measure experimentally the integral volume changes calculated in the paper. She had already given some thought to these subjects. He was of the opinion that the space above the cathode was ample, and that the value of δ, in so far as its value depended on changes in the concentration of the solution of copper sulphate was correct. If the variations in concentration had been so great as to vitiate the value of δ, then, owing to the equalising effect of diffusion, an appreciable change would have taken place in the weight of the cathode vessel and contents after the conclusion of an experiment.

Mrs. Griffiths has communicated the following comments on Mr. Shaxby's remarks: The mathematics in the second and third paragraphs appears to be correct and is interesting, but the first paragraph would seem to be somewhat misleading in that the necessity is not avoided for relying on data (dealing with concentrations) obtained by other workers. Mr. Shaxby avoids the necessity by making an hypothesis in the last paragraph which is not justifiable, for when the current has ceased the value of δ cannot depend on the process whereby the salt has been eliminated. Even during the passage of the current the process can have only an inappreciable effect on the value of δ.

A paper entitled "*Note on an Explanation of the Migration of the Ions*," was read by Dr. S. W. J. Smith, M.A., F.R.S.

The object of this Note is to show how a familiar diagram, appearing in many text-books, can be improved in a way which makes it easier to appreciate what happens at the electrodes in the simpler examples of Hittorf's method of determining the migration constant. An attempt is made to give precision to an idea which is sometimes vaguely expressed and frequently ignored.

Discussion.—Mr. D. Owen considered that the usual graphical method expressed the integral effect simply and satisfactorily unless pressed in detail. The analysis of paragraph three of the paper, whilst adding precision to the conclusions, did not modify them or "explain" them. The fact of the existence of a volume distribution of electricity near to the electrodes implied an increased potential gradient which played a part in the actions occurring in those regions.

Dr. Willows suggested that, if Mr. Owen's view were correct, it should be possible to detect the potential gradients to which he referred.

Mr. F. E. Smith remarked that Dr. Smith's paper dealt with a real difficulty, and one which teachers of electricity had to face. He remembered giving lectures on the subject to very elementary students, and, feeling dissatisfied with the explanatory diagrams in text-books, had adopted another form of explanation. In dealing with the phenomenon the negative ions were never said to be discharged. The general argument followed was to regard matter as being in four states — solid, liquid, gaseous and ionic. It was already conceded from analogies that copper ions and metallic copper differed because of a difference of electrical energies. Conversion from one into another could be brought about by adding or subtracting electrical energy. Thus, in the electrolysis of copper sulphate solution with copper electrodes, the electrode at high potential lost energy by conversion of a part of itself into positive ions, and the negative electrode gained energy from the solution due to positive ions giving up their charge and being converted into the metallic form.

Dr. Smith, in reply, said:—In the original draft of the Note, as submitted to the Society, he had hazarded the opinion that perhaps the authors, who used the diagram, wished it to be understood that the excess ions shown at the ends of the chains were removed by excess potential gradients. He had deleted this conjecture, and had substituted a footnote (which was, in fact, a quotation), because he had been unable to find any proof that this was the view taken. In any case it was unsatisfactory. Mr. Owen seemed to imagine that there was some virtue of simplicity about this view which made the analysis of § 3 unnecessary. This was not the case. The problem was not merely to state how a Hittorf migration experiment might be supposed to begin. It was as necessary to show clearly what occurred while it continued. This was the object of the Note. The analysis of § 3 was the simplest general method of expressing the fact that some of the ions which take part in the electrolytic process are fed into the circuit near the electrodes, and are not brought there by the potential gradients. Views which "explain" the facts, while ignoring this, have been the cause of needless confusion in the minds of students. The analysis of § 3 showed, for example, that conduction could not proceed as it began unless for every $(u+v)$ cations deposited v cations and v anions were fed into the circuit at the cathode. If the cathode region had to draw upon itself for this supply of ions, the concentration near it would rapidly fall, and the "polarisation" at the cathode would rise in accordance with the well-known relation connecting the contact potential difference with the concentration. Diffusion, however, always played an essential part. When it was promoted by convection, a slight reduction in the concentration of the solution round the cathode would be enough to set up an appreciable diffusion current which would be maintained in the way described in § 4 of the Note. This was the current which supplied the necessary molecules to the cathode space. The relation between this diffusion current and the electric current could be represented by the equation $k\,n = v\,i/(u+v)\,e$, where k is a diffusion constant, n is the concentration gradient at the cathode, i is the electric current density, and e is the ionic charge.

If, notwithstanding this re-expression of his views, which he had thought were adequately conveyed in the note, Mr. Owen still insisted that the usual graphical method was satisfactory, he could think of no better method of convincing him that it was not than to ask him to examine more closely the consequences of his own view as expressed at the meeting. He would then be led to the conclusions stated in the Note.

Since the point had been raised, it should, perhaps, be noted that there was an obvious clerical error in the proofs of the paper whereby N, N′ and N″ had been printed throughout instead of S N, S′ N′ and S″ N″ respectively. With regard to the question raised by Dr. Willows, he was of the opinion that measurable potential differences of the kind described did not exist. He was glad that the chairman was of the same opinion as himself with respect to the diagrams and descriptions usually given.

A paper, by Dr. S. W. J. Smith, entitled "*A Method of Exhibiting the Velocity of Iodine Ions in Solution*," was taken as read. The method was shown.

Dilute solutions of potassium iodide and potassium chloride of equimolecular concentration have almost the same electric conductivity. They are therefore of interest in connection with the direct measurement of ionic velocities. The paper describes a simple method of observing their common boundary. It is only necessary to add a little mercuric chloride to the potassium chloride solution. An extremely thin layer of mercuric iodide then forms where the two solutions meet. The method is particularly convenient for lecture purposes, and an approximate value of the ionic velocity can be obtained in a few minutes.

The paper gives examples of the use of the method. The current is first passed in the direction which causes the iodine ions to travel towards the chloride. The chlorine liberated at the anode in this case supplies a means of redetermining the velocity of the ions when, the current being reversed, they move in the opposite direction.

COLONIAL AND FOREIGN ENGINEERING PROJECTS.

WE give below a few data on several colonial and foreign engineering projects, taken from the *Board of Trade Journal*. Further information on these projects can be obtained from the Commercial Intelligence Branch, Board of Trade, 73, Basinghall-street, London, E.C.

Canada: According to telegraphic information received at the office of the High Commissioner in London for Canada, a Bill is to be introduced during the coming session of the British Columbia Legislature to authorise the Government to build 30 four-masted schooners, fitted with auxiliary Diesel engines, to be used in the lumber-carrying trade.

Portugal: The *Diario do Governo* publishes a Bill, which has recently been presented to the Portuguese Chamber of Deputies, to authorize the Municipality of Amarante to contract a loan of up to 120,000 escudos (about 17,500*l.* at current rate of exchange) to be devoted to a hydro-electric installation for the production of power for lighting and other purposes; the construction of a market in Amarante; water supply and sewage systems, &c. The *Diario* also contains a Bill, which has been presented to the Chamber of Deputies, to authorise the Municipality of Sobral de Monte Agraço to sell certain property, with a view to devoting the proceeds to the construction of a municipal slaughterhouse, and also, should there be any surplus, a school building.

Spain: The *Gaceta de Madrid* publishes a notice to the effect that tenders will be opened at the Dirección-General de Obras Públicas, Ministerio de Fomento, Madrid, on May 31, for the construction and working, for a period of 99 years, of a secondary railway from Alicante to Alcoy. The cost of construction is estimated at 13,478,236 pesetas (about 539,000*l.*), on which interest not exceeding 5 per cent. per annum will be guaranteed by the State. The minimum rolling stock required to work the line will be six locomotives, 20 passenger coaches, seven brake vans, and 58 goods wagons. Construction work must be commenced within a period of three months from the date of the notification of the award of the concession, and must be completed within four years from the same date. Although the foregoing contract will probably be awarded to a Spanish firm, nevertheless the carrying out of the works may involve the purchase of some materials outside Spain. With reference to calls for tenders by the Municipality of Barcelona for the carrying out of street drainage and sewerage works in that city, it is announced in the *Gaceta de Madrid* that tenders will be opened at the Casa Consistorial, Barcelona, on May 12, for the carrying out of further similar work in Barcelona at a total estimated cost of 411,464 pesetas (about 16,460*l.*). The conditions of contract contain clauses to the effect that at the first competition the materials to be used will be confined, with certain exceptions, to products of Spanish manufacture, but that, in the event of no decision being arrived at, a second competition, in which foreign products may be accepted, will then take place. In the latter event Spanish products will have a 10 per cent. margin of preference over foreign.

Siam: The Acting British Consul-General at Bangkok has forwarded a copy of a specification and tender form in connection with a call for tenders by the Siamese Royal Irrigation Department, as follows:—Sealed tenders, on the proper forms, will be received up to noon on August 1 by the Director-General of the Royal Irrigation Department, Bangkok, for the supply and delivery of a suction or hydraulic dredger. The length is not to exceed 150 ft. and the beam 18½ ft. The draught must not be more than 4½ ft. when the dredger is in full working order.

THE AMERICAN DYESTUFF INDUSTRY.—According to the *Iron Trade Review*, Cleveland, Ohio, Dr. Norton, the author of a report on the present dyestuff situation issued by the Bureau of Foreign and Domestic Commerce, has expressed the opinion that the United States is to have a permanent dyestuff industry. The textile and allied industries, he says, are united in the determination that the country shall not again be exposed to such a famine as it has recently experienced. The large organisations of dyestuff users have expressed a willingness to bear the burden of higher prices than prevailed before the war, if necessary. Most of the companies engaged in manufactoring coal-tar compounds are planning to continue their production along the lines already taken up and to enlarge such production, or enter upon the manufacture of additional intermediate or finished dyes, as circumstances warrant.

NORWEGIAN MERCANTILE MARINE.—We read in the *Anglo-Norwegian Trade Journal* that the Norwegian mercantile marine during February, 1916, showed an increase of 35 ships, with a total tonnage of 36,941, and a decrease of 20 ships, totalling 12,305 tons. Two steamers, of 2202 tons, have been lost through war causes, while 22 ships, totalling 29,812 tons, have been purchased from abroad. The net result of the month is that the steamship fleet has increased by 14 ships, with a tonnage of 25,871, and the fleet of motor ships by seven vessels, with a tonnage of 3333; on the other hand, the sailing fleet has further decreased by six ships and 4568 tons, whereby the fleet as a whole shows an increase of 15 ships, with a total tonnage of 24,636. Compared with previous months, the net increase was as follows:—During November, 30 ships and 50,223 tons; during December, 8 ships and 34,914 tons; and during January, 8 ships and 27,840 tons. The net increase of the fleet for the first 19 months of the war (August 1, 1914, to February 21, 1916) amounts to 137 ships and 246,499 gross registered tons.